FIRST PRINCIPLES

OF

OTOLOGY

A TEXT-BOOK FOR MEDICAL STUDENTS

BY

ALBERT H. BUCK, M.D.

NEW YORK CITY

Clinical Professor of the Diseases of the Ear, College of Physicians and Surgeons, Medical Department of Columbia University, New York;
Consulting Aural Surgeon, New York Eye and Ear Infirmary and the Presbyterian Hospital

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PREFACE.

The complaint has frequently been made—and rightly, as I believe—that the larger treatises on otology contain a great deal of material which, however useful it may be to men who propose to treat diseases of the ear, is practically of little value to medical students, of whom a knowledge of only the first principles of this branch of surgery is required for graduation. For such readers, therefore, a much smaller work—one that treats only of the fundamental facts and theories relating to the anatomy, physiology, pathology, and therapeutics of the ear—should amply suffice. The present little book is the outcome of an attempt to supply such a manual for the exclusive use of undergraduate medical students.

ALBERT H. BUCK.

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FIRST PRINCIPLES OF OTOLOGY.

CHAPTER I.

METHODS OF EXAMINING AN EAR.

1. In the Examination of all Cases of Ear Disease it will be Found Advantageous to Adopt a Routine Plan of Procedure.

First, the history of the trouble, whatever it may be, should be obtained from the patient or—in the case of a child—from the parents or guardian. Then the hearing of both ears should be tested (watch and voice tests) and a note should be made of the results ascertained. The tuning-fork test should be applied next. If the case be one in which pain has been mentioned among the symptoms, a careful search should be made, both by palpation and by inspection, for redness, tenderness, or swelling of the skin in the vicinity of the affected ear, and for the existence of enlarged glands either on the side of the neck, high up, or over the mastoid process. These steps should be followed by an examination of the external auditory canal and tympanic membrane with the aid of speculum and reflected light. Then, finally, the patient's fauces, pharyngeal vault, and nasal cavities should be subjected to a careful examination; and this should be done even in those cases in which the walls of the external auditory canal appear to be the seat of the principal disorder.

In not a few instances this scheme of procedure will have to be amplified by a further inquiry into the patient's past ailments, mode of life, and family history.

2. The Watch Test.

In testing the hearing by means of a watch, care should be taken to employ one which ticks rather loudly. So far as the test itself is concerned, it is better to hold the watch first at a point which lies beyond the range of hearing of the ear which is being tested, and then gradually to bring it to the point at which the patient is able to distinguish the sound of the ticking. The distance of this point from the patient's ear represents the hearing distance for that particular ear. The other ear should be kept closed during the progress of the test. When the sound of the ticking cannot be heard through the air, it may often still be rendered audible by pressing the watch against the auricle or against some part of the head (mastoid region, temple, teeth).

3. The Voice Test.

The employment of spoken words, as a test of the hearing power, is involved in many difficulties. Very few physicians can command the requisite amount of space in their offices, and a still smaller number are able to maintain on all occasions, when the test is applied, the same degree of loudness and distinctness of enunciation. Hence this test is, at best, a very crude one.

The following precautions must be observed: The ear which is not being tested should be closed quite firmly. The patient should also sit in such a position that the physician's voice may be thrown directly against the ear which remains open, *i.e.*, at right angles to that side of the head. The patient should be required to repeat the exact words (*e.g.*, numbers) spoken by the physician. If the room is

so small that the maximum distance at which words spoken in an ordinary tone of voice cannot be ascertained, whispered words will have to be employed instead. The results of these tests are to be recorded, and at some later date the experiment should be repeated. By a comparison of the results obtained at these different trials, some idea, although perhaps not a very accurate one, may be obtained of the effects produced by the treatment employed.

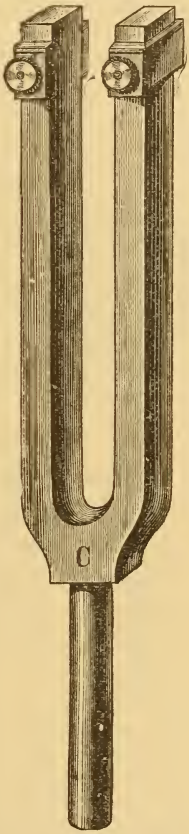

FIG. 1.—Heavy Prismatic Tuning-fork with Movable Clamps. (Reduced ⅓.)

4. The Use of the Tuning-Fork.

A heavy prismatic fork, of low pitch (C, for example) and provided with movable clamps attached near the free end of each arm, will be found sufficient for all ordinary purposes. By striking one of the arms of the instrument lightly upon his knee the surgeon can call forth sonorous vibrations which will continue audible for a period of several seconds—*i.e.*, long enough to enable him to place the handle of the fork on the patient's forehead, just above the bridge of the nose, and to permit the patient to observe calmly in which ear the sound preponderates. If the preponderance of sound is in the affected ear, all serious disease of the cochlear structures, or of the auditory nerve at some other point in its course, may at once be excluded; or, in other words, it may safely be assumed that the disease is located either in the tympanic cavity, or in the Eustachian tube,

or in the external auditory canal. On the other hand, it is not always safe to draw the conclusion that the nervous structures of the deficient ear are at fault when the patient refers the preponderance of sound to the well-hearing ear. The latter, which he supposes to be normal in every respect, may nevertheless be plugged to some extent with inspissated cerumen or other obstructing material; in which case it will not be surprising if the phenomena of reflection and increased resonance, in the supposedly sound ear, should completely nullify all phenomena which might otherwise throw light upon the condition of the fundamentally affected ear. An error of this kind, however, will be readily rectified by an examination of both ears with the speculum and reflected light, and, if necessary, by a repetition of the tuning-fork test after the removal of the mass of cerumen.

5. Weber's Experiment.

Weber discovered that when he closed the orifice of one external auditory canal (both ears possessing normal hearing power), and rested the handle of a vibrating tuning-fork firmly upon the vertex of his head, the sound produced by the fork seemed to reach the closed ear with decidedly greater force. He attributed this preponderance of the sound to the resonance of the air in the closed external auditory canal. Politzer holds that this increase in the loudness of the sound heard in the closed ear is due not only to increased resonance of the air contained in the external auditory canal, but also in a measure to an increase in the volume of sound reflected back to the auditory nerve through the changed tension of the conducting mechanism —the membrana tympani and ossicles.

In all cases in which there is a swollen or thickened condition of the tympanic membrane, or in which some obstruction exists in the external auditory canal, Weber's experi-

ment will show a decided predominance of the sound of the fork in the affected ear. On the other hand, if the nervous apparatus of one ear is affected, the predominance of the sound will be in the healthy ear.

6. Rinne's Experiment.

Rinne made the observation that persons with normal hearing are able to hear the sound of a vibrating tuning-fork held in front of the auricle, after they have ceased to hear the same fork by direct bone conduction through the teeth and skull, or through the skull alone. When this test is applied to an ear which is deficient in hearing-power, and it is found that the sound of the vibrating-fork (which must have a comparatively low pitch) is not heard when it is transferred from the skull to a point directly in front of the outer orifice of the auditory canal, the conclusion is fairly warranted that the cause of the impaired hearing is to be sought for in some defect of the conducting apparatus and not of the auditory nerve or its terminal mechanism. This test, so far as I am now able to judge, possesses a very limited value.

Fig. 2. — Galton's Whistle. (Reduced ½.)

7. Galton's Whistle and König's Steel Rods.

Sounds of a very high pitch may be obtained from both of these instruments, and they therefore furnish us with the means of ascertaining to what extent, if at all, a patient's range of audition, in the direction of the higher tones, is limited. However, it is still a matter of uncertainty whether this limitation of the power to distinguish very high notes signifies a cochlear lesion or one confined to the transmitting apparatus of the middle ear.

8. Ear Specula.

Three kinds of cylindrical or cone-shaped ear specula are in common use—Toynbee's, Wilde's, and Gruber's. The first-named (Fig. 3) is objectionable because its smaller end is more likely than is that of either of the other two specula to injure the walls of the auditory canal. Wilde's specula (Fig. 4), which are perfectly conical in shape, are, on the whole, the most useful of the three patterns; although many aural surgeons still give the preference to the Gruber model (Fig. 5).

FIG. 3.—Toynbee's Ear Specula.

FIG. 4.—Wilde's Ear Speculum.

FIG. 5.—Gruber's Ear Speculum.

9. Reflectors.

Concave mirrors, which cause the rays of reflected light to converge to a focus situated at a distance of from seven to twelve inches from the plane of the mirror, are the reflectors commonly employed in examinations of the deeper parts of the ear. As a rule, these mirrors are attached, through the medium of a ball-and-socket joint, to a forehead-plate of metal or hard rubber; an arrangement which permits the instrument to be worn upon the surgeon's head, and leaves his hands free for the various manipulations which facilitate an examination of the ear. Some surgeons

employ the mirror in the manner shown in Fig. 7, while others prefer to have it occupy such a position that the observing eye may look directly through the central aperture in the mirror. Personally, I prefer the first of these methods; for I found, after a trial of both, that it was more convenient and at the same time less fatiguing than the other method.

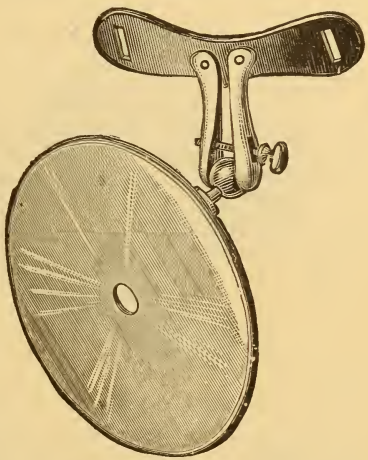

FIG. 6.—Forehead-mirror. (Half the natural size.) (For cut of mirror in actual use, see the next figure.)

10. Anatomical Points which Have a Direct Bearing upon the Subject of the Introduction of the Aural Speculum.

In infancy the external auditory canal is composed mainly of soft tissues, and the drum membrane lies but little below the level of the surrounding surface of the skull. The latter membrane, at this early period of life, faces chiefly downward; that is, it forms, with the long axis of the auditory canal, a decidedly obtuse angle (see Fig. 9). The walls of the canal, not having any support below and on their

FIG. 7.—Forehead-mirror in Actual Use.

sides, tend to collapse against the surface of the skull. Before introducing a speculum, therefore, into the auditory canal of an infant, it is necessary to pull the auricle outward and a little downward, for it is only in this way that the canal can be given its full dimensions as a cylinder. It also should be remembered that at birth the little ring of bone—the annulus tympanicus (Fig. 10)—in which the tympanic membrane is set, and to which the membranous meatus is firmly fastened, is itself very feebly attached to the squamous portion of the temporal bone.

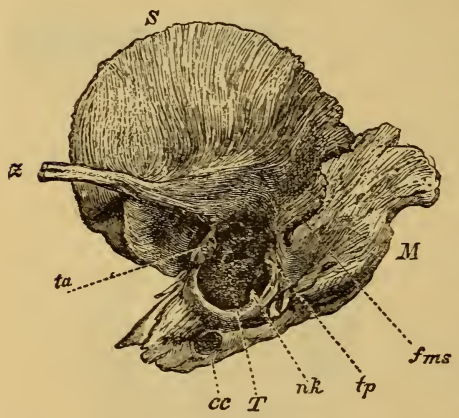

Fig. 8. — Temporal Bone of a New-born Child. (After Gruber.) *S*, squamous portion; *M*, mastoid portion; *Z*, zygomatic process; *T*, tympanic cavity; *fms*, fissura mastoideo-squamosa; *cc*, foramen caroticum; *ta*, *nk*, *tp*, points where the annulus tympanicus is beginning to develop spurs of bone.

In adults the outer, cartilaginous portion of the external auditory canal tends to droop downward and forward (see Fig. 11). This is explained by the fact that the framework of this portion of the canal is composed, not of a solid plate of cartilage, but of one which has gaps (fissures of Santorini) that are placed transversely to the long axis of the canal, and that are filled in with elastic

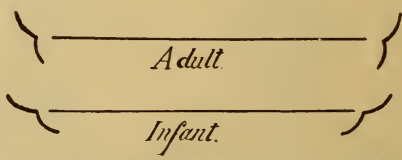

Fig. 9.—Diagram showing Inclination of the Membrana Tympani in Infancy and in Adult Life.

tissues (see Fig. 12). Hence, in introducing a speculum into the external auditory canal of an adult, it is necessary, as a rule, first to pull the auricle upward and a little backward; by which procedure the long axis of the drooping portion of the canal will be brought into a line with that of the osseous or membranous portion.

Fig. 10.—Annulus Tympanicus, at Birth.

In old age the flexibility of this part of the ear is apt to be greatly diminished by various pathological alterations which occur in both the fibrous and the cartilaginous tissues.

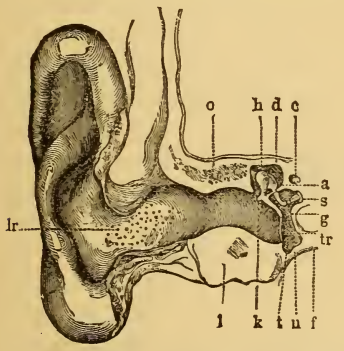

Fig. 11.—Vertical Section through the Right External Auditory Canal, Drum-membrane, and Middle Ear. *o*, Cellular spaces in the upper bony wall of the canal (these cells communicating with the cavity of the tympanum); *d*, roof or tegmen of the tympanum; *t*, tympanum; *u*, lower wall of the same; *tr*, membrana tympani or drum-head; *h*, head of hammer; *a*, anvil; *s*, stirrup; *c*, canal of Fallopius; *f*, fossa jugularis; *dr*, mouths of glands at orifice of the external auditory canal. (After Politzer.)

11. Sources of Light.

Ordinary daylight, such as can be obtained by directing the hand- or the forehead-mirror toward the sky (not toward the sun) or toward the white wall of a house near by, will usually afford a sufficient degree of illumination

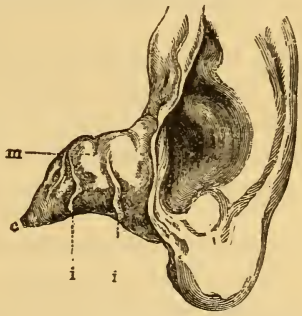

Fig. 12.—Auricle and Cartilaginous Portion of the External Auditory Canal. *m*, Cartilaginous meatus; *c*, inner pointed end of the same; *ii*, fissures of Santorini (incisuræ Santorinianæ)—Left ear. (After Politzer.)

for examinations of the deeper parts of the ear. Many surgeons, however, prefer to use artificial light—such as an ordinary gas flame, the Welsbach light, or the incandescent electric light. When these more brilliant sources of light are not obtainable, simple candle light will generally be found sufficient.

12. Position of the Patient in Relation to the Surgeon and to the Source of Light.

The surgeon should, if possible, be seated in such a manner that his eyes shall be on a level with the ear to be examined; and the light should come preferably from a point located on his left-hand side and a little higher than (or at least on the same level as) the patient's ear. It is desirable that the light should come from the left, in order that the movements of the surgeon's right hand—the one commonly employed for manipulations in the auditory canal —may not, at a given moment, cut off the rays which fall upon his reflecting mirror, and so rob the field of vision of its illumination. Finally, the patient's head should be placed in such a position that the long axis of the auditory canal about to be examined shall coincide, as nearly as possible, with the surgeon's line of vision.

13. Mode of Introducing the Speculum.

The ear to be examined, let us suppose, is the left one, and belongs to an adult. Holding the speculum between the thumb and forefinger of his left hand, and lifting the auricle upward and backward with his right, the surgeon should introduce the former cautiously into the orifice of the canal. As he pushes the instrument farther and farther inward, by a sort of boring motion, he should keep his eye directed upon the parts illuminated at the bottom of the speculum. By thus watching the progress of the farther end of the instrument, he should be able to introduce it as

far as he may find desirable, without causing the patient pain or even discomfort.

With regard to the question of how far the speculum should be introduced into the meatus, it may be said that as soon as the instrument has reached a position in which a clear view of the membrana tympani and deeper portions of the canal can be obtained, nothing will be gained by pushing it farther inward.

14. Accessory Instruments Often Needed in Examinations of the Ear with the Speculum.

It is frequently impossible to obtain a view of the tympanic membrane and neighboring parts of the auditory canal until certain obstructing substances—such as cerumen, hairs, scales of epidermis, etc.—have been removed. For the accomplishment of this task one or more of the following instruments will be required: angular forceps, cotton carriers, slender probes and curettes, and a suitable syringe.

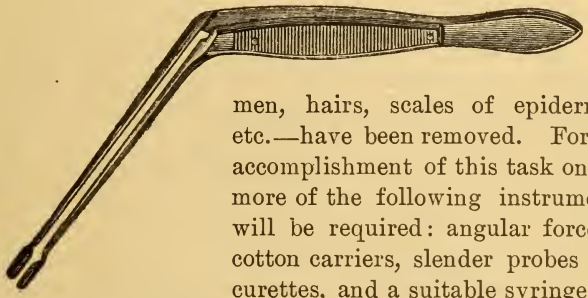

Fig. 13.—Politzer's Angular Forceps. (Reduced ½.)

Two grades of *angular forceps* are needed: a fairly strong pair, with which the more solid masses may be grasped (Fig. 13), and one more delicately constructed—with which, for example, a hair or a thin flake of epidermis may be seized.

The *cotton carrier*, a slender cylindrical rod of flexible steel, mounted in a short handle of aluminium (Fig. 14), is a most useful instrument. It serves—when absorbent cotton has been wound around its free extremity—the purposes of a mop.

Probes and *round-edged curettes* are also important accessory instruments. By means of the former we may touch and manipulate various objects which unaided vision might very easily misinterpret. A properly constructed curette, on the other hand, is a lever by means of which any object which adheres to the walls of the auditory canal, or even to the membrana tympani, may readily and painlessly be separated from the part to which it is attached.

FIG. 14.—The Harrison Allen Cotton-carrier.

As a broad rule, the surgeon who is intent upon making a correct diagnosis should employ the *syringe* only when the conditions in the auditory canal are such as to render its employment almost unavoidable. The following suggestions will perhaps aid the beginner in determining whether he shall use the syringe or one of the instruments previously mentioned:

1. Small objects, like hairs, scab-like formations, etc., can always be readily got out of the way by aid of the curette or the slender forceps, or by wiping them away with a little cotton wound around the end of a cotton-carrier.

2. Hard cerumen or laminated masses of desquamated epidermis should be loosened from the surrounding walls of the auditory canal by means of the curette, and should then be removed either with the angular forceps or by means of the curette after it has been given a suitable curve.

3. If the steps just described fail to remove all of the obstructing mass, and it is found that the inner part remains wedged in between the membrana tympani and the anterior and upper wall of the canal, a persistent effort should be made to open (by means of the curette) a

small passage, between the mass and the upper wall of the canal, as far inward as to the membrana tympani. Then, by directing the stream of water from the syringe toward this artificial channel, one may often succeed in exerting a *vis à tergo* sufficient to dislodge the impacted mass.

Fig. 15.—Slender Silver Ear-probe. (⅔ actual length.)

4. Soft cerumen (if at all abundant) or a large quantity of foul-smelling pus should preferably be removed by syringing.

A hard-rubber syringe, like that represented in Fig. 17, will be found, in the hands of the surgeon, to answer well all the requirements of a good ear syringe. The water employed in syringing the ear should have a temperature of about 100° F. For the purposes which are here under discussion, ordinary non-sterilized water is sufficiently safe. It is a good rule, in syringing an ear, to ask the patient from time to time, during the progress of the operation, whether he or she experiences either dizziness or faintness; for when these symptoms appear the operation should be suspended.

Fig. 16.—Steel Curette with Rounded Edges. (⅔ actual length.)

15. Explanation of Certain Terms in Common Use.

The domain of the ear is very generally spoken of as comprising three subdivisions; viz., the external, the middle, and the internal ear. The *external ear* includes both the auricle and the external auditory canal. The expression "*middle ear*" is often employed synonymously with that of "tympanic

cavity"; but when the term is used in its stricter sense it is intended that it shall include, besides the tympanic cavity proper, the Eustachian tube and all that system of pneumatic spaces which are situated behind, above, below, and outside the tympanum, and which receive their air-supply from this central cavity. The term "*internal ear*" is ap-

FIG. 17.—Hard-rubber Ear-syringe.

plied to that complex system of cavities which are known more specifically as the vestibule, the cochleal whorls, the semi-circular canals, and the aquæductus vestibuli and aquæductus cochleæ. The term "*labyrinth*" is synonymous with that of internal ear, and is employed—on the whole—more frequently than the latter.

When I come to discuss the diseases of these different subdivisions of the ear, I will give further details relating to the anatomy of each and to the methods of examining them.

CHAPTER II.

DISEASES OF THE AURICLE.

1. Anatomical Considerations.

The framework of the auricle is composed of fibro-cartilage. Over this is spread, first, the perichondrium—an enveloping membrane which bears to this framework the same relationship which the periosteum does to a bony structure; then a scanty layer of connective tissue; and, finally, the skin. All these overlying parts are supplied with nerves, lymphatics, and blood-vessels. The arterial supply of the auricle is derived entirely from branches of the external carotid artery. The most important of these is the posterior auricular artery, which supplies the posterior aspect of the auricle, the neighboring part of the cartilaginous external auditory canal, and that part of the fossa conchæ which is situated farther back than the meatus auditorius. The arterial twigs which supply this latter region pass directly through the intervening cartilaginous framework of the auricle. Another arterial branch of importance is the superficial temporal artery. This vessel gives off the anterior auricular arteries, which supply the lobule, the tragus, the anterior wall of the cartilaginous portion of the external auditory canal, and the anterior and upper part of the helix. The return current of venous blood passes through veins which follow the same course as do the corresponding arteries. The anterior auricular veins pour their blood into the superficial temporal vein, the posterior auricular into the external jugular, and the

deep auricular into the internal maxillary, by way of the pterygoid plexus. The different names which have been given to the different parts of the auricle may easily be ascertained by consulting the accompanying cut (Fig. 18).

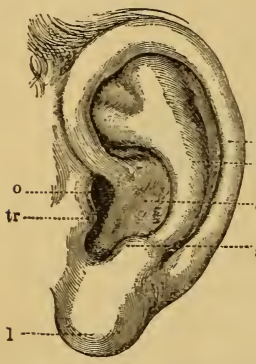

Fig. 18.—Auricle. *ah*, Antihelix; *at*, antitragus; *c*, concha (fossa conchæ); *h*, helix, the grooved portion of which is termed the fossa helicis; *l*, lobule; *o*, orifice of external auditory canal; *tr*, tragus. The notch between the tragus and the antitragus is called the incisura intertragica. (After Politzer.)

2. Pathology.

The diseases to which the auricle is liable are, in the main, those which affect the skin generally and those which attack cartilaginous structures. Eczema, perichondritis, softening of the cartilage (chondromalocosis), and new-growths constitute, therefore, the major part of the list. Congenital malformations belong among the rarities; and injuries, burns, and frost bite are not encountered particularly often.

3. Eczema.

Among the children of the poorer classes, eczema of the auricle is an extremely frequent disease. If less frequent among the children of the well-to-do classes, it is certainly by no means a rare affection even among them. Again, in old age and in the middle period of life it is quite a common disease. In a certain percentage of the cases it develops on other portions of the skin at the same time, as, *e.g.*, on the hairy scalp or in the mastoid region. In children it is often associated with a conjunctivitis, and the coexistence of the two diseases suggests the probability that the irritating secretions of the auricle have been transferred by the child's fingers to the eyes.

In its mildest and simplest form, eczema of the auricle manifests itself as a reddening and infiltration of the skin at one or more points. The favorite places are those spots where the skin is folded upon itself, as the fossa helicis, and the angle behind the ear, where the skin is reflected from the auricle upon the mastoid process. The disease is observed at least equally often at the orifice of the external auditory canal, and extending from there forward over the tragus, and downward over the lobule—in other words, at points where there is apt to be a good deal of friction, or where an irritating discharge from the meatus may act as an exciting cause. At a later stage these reddened and infiltrated spots secrete a fluid which soon becomes inspissated, forming crusts or scabs. In many cases actual ulceration takes place beneath the scabs; and this is particularly apt to occur in the incisura intertragica, in the fossa helicis (see Fig. 18), and in the angle behind the ear. In exceptional cases the entire auricle and immediate surroundings present an almost continuous mass of scabs.

In another group of cases, a desquamative process, confined to certain portions of the auricle, seems to constitute the most characteristic, if not the only, manifestation of the disease. The intervening portions of the skin appear to be perfectly healthy, and even those parts which are desquamating or are covered with scab-like formations often present a pale and uninflamed appearance. The term chronic eczema is usually applied to this class of cases, but it may be applied with equal justice to almost all cases of eczema of the ear in adults.

When a well-marked gouty attack involves the fingers or toes, a spontaneous and sometimes very striking subsidence of the eczema of the ear is observed. A vigorous purge will also at times produce the same beneficial effects. Every now and then in the course of a chronic eczema, the auricle passes through an attack of what appears to the

observer to be erysipelas. The organ becomes uniformly red, swells up to two or three times its natural size, pits on pressure, and is painful to the touch. Gradually, the redness and swelling disappear, and the auricle, in the course of four or five days, returns to its former state. Whether these attacks, which recur repeatedly in certain cases—sometimes as often as twice in the course of a month—are really erysipelatous in character or simply represent a diffuse acute exacerbation of the eczema, I am unable to say. As the inflammation does not extend beyond the auricle and external auditory canal, and as there is very little constitutional disturbance, it would seem more proper to look upon it as non-erysipelatous in character.

Etiology.—In infants and young children an outbreak of eczema of the auricle may almost always be traced to disordered digestion (gastro-intestinal), the result of unsuitable feeding. Habitual overfeeding may pròduce the same pathological lesions in an adult, especially if the individual be a person of sedentary habits; but, in the majority of these cases, we are obliged to look for the cause in that more permanent disturbance of the metabolic changes which is termed goutiness or lithæmia.

The *prognosis* of the disease is good. In the majority of cases we may confidently expect to restore the auricle to an apparently natural condition in a short time. In children, particularly, we may look for a very prompt clearing up of the affected skin, and the cure is likely to prove permanent. In persons past middle life it is well to give a more guarded prognosis; for although we may succeed in promptly restoring the part to a seemingly healthy condition, a relapse is almost sure to come, and that, too, at an early day. The gouty or lithæmic state is the real disease in these cases, and not this limited area of inflammation of the ear. Hence the temporary character of the effects produced by local treatment.

Treatment.—In children the adoption of a diet of simple, easily digested food, and the careful regulation of the bowels, constitute the most important part of the treatment. In addition to these general measures, it will also be found useful to employ a certain amount of local treatment. The inflamed skin should be gently cleansed with Castile soap and tepid water at least once a day. Then, after carefully drying the parts, some suitable oleaginous preparation should be applied, and means should be adopted for protecting the auricle from friction. The chief value of the oleaginous preparations lies, I imagine, in their power to exclude the air (with its irritating charge of dust, etc.) from the parts affected, rather than in the medicinal virtues of the drugs which enter into their composition.

In those cases in which actual ulceration has taken place, the crusts which generally cover these ulcers must first be removed, and then silver nitrate, in the form of a bead fused upon the end of a probe, should be passed firmly but quickly over the raw surface. Oftentimes a single such cauterization will effect a prompt healing of the ulcer.

While an acute exacerbation of the disease is in progress, cloths dipped in some cooling and astringent lotion, such as the lead-and-opium wash, or in simple water to which a small quantity of alcohol or *eau de Cologne* has been added, should be wrapped around the inflamed auricle; and means should be provided for renewing the cloths as often as may be rendered necessary through their becoming partially dry. In an exceptionally severe exacerbation it may be found advisable to apply one or two leeches, either directly behind the affected auricle or to the region immediately in front of the tragus.

4. Hæmatoma Auris; Perichondritis. (Othæmatoma; Chondromalacia; Chondromalacosis.)

These conditions are so closely allied to each other that it is better, I believe, to consider them together in one section. The term hæmatoma auris, or othæmatoma, is usually applied to a peculiar swelling of the auricle, which is most frequently observed in the insane, and which is chiefly due to the escape of a varying quantity of blood either between the cartilage and the perichondrium, or into the substance of the cartilage, some of which undergoes death. The term perichondritis should be restricted to those cases in which the symptoms of redness, pain (usually slight), and slowly increasing swelling point very decidedly to processes that are chiefly inflammatory in their nature.

Exposure to severe cold or a high degree of heat produces in the auricle an inflammation to which the term "simple perichondritis" may properly be applied. Severe bruising of this organ is often followed by pathological changes of the same nature. Perfect health affords no exemption from an attack of simple perichondritis, whereas a poor state of general nutrition seems to be a prerequisite for the development of a typical othæmatoma, in which the actual breaking down and death of a limited portion of the cartilage constitute the starting-point and most essential part of the disease (a genuine chondromalacosis). Unfortunately, it is very often impossible to decide, until after the lapse of a considerable period of time, whether, in a given case, we are dealing with an attack of "simple perichondritis" or with one which is essentially a "chondromalacosis." Under these circumstances, therefore, we may be permitted to use either of these terms indifferently.

In a case of well-advanced othæmatoma the alterations produced in the external appearance of the auricle are very

striking. Where the skin is not stretched by an abundant exudation of fluid between it and the cartilaginous framework, as is the case in the upper part of the auricle shown in Fig. 19, its surface will present an irregular appearance (see Fig. 20).

Treatment.—Cases

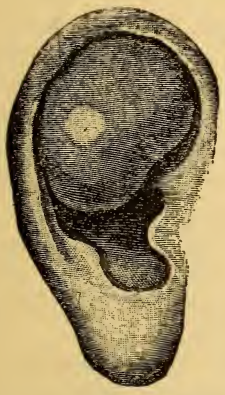

Fig. 19.—Hæmatoma of Upper Part of Auricle. (After Bürkner.)

Fig. 20.—General Perichondritis of the Auricle, with areas of destructive chondromalacosis, resulting in marked diminution in size of the entire organ. (After Benni, in *Comptes Rendus du Troisième Congrès International d'Otologie ;* Bâle, 1885.)

of perichondritis or of chondromalacosis of the auricle rarely come into the physician's hands until a distinct cavity, with fluid contents, has formed. The most urgent indication in this stage of the disease is to relieve the tension and prevent further separation of the perichondrium from the cartilage. This can best be accomplished by making an incision into the swelling; not a small one, which will allow only the fluid portions of the contents to escape, but a liberal one, that will afford ample room for the removal of all dead tissue and for the thorough daily cleansing of the cavity. If the cartilage seems to be

in a healthy condition, we may begin at once, on the day following the incision, to bring moderate pressure to bear upon the separated cartilage and perichondrium, in the hope of thus hastening their union by adhesion. In addition to the daily cleansing of the cavity with a tepid bichloride-of-mercury solution (1: 5,000), and the readjustment of the pads and bandages, it is doubtful whether we can do anything that will materially hasten the process of healing.

5. New-Growths.

The commonest form of new-growth of the auricle is the *fibroid tumor*. While it is of somewhat rare occurrence among white women, it is often encountered among negresses. The exciting cause, in most cases, seems to be the operation of piercing the lobule, or the irritation produced by wearing an ear-ring. These growths occasionally reappear, even after the original tumor has been, so far as one can judge, thoroughly extirpated. So far as their size is concerned, they rarely exceed the dimensions of a fairly large cherry.

Among the other-new growths which sometimes develop in the auricle, the following may be mentioned: epitheliomata, horny growths, syphilitic gummata, lupus, and angiomata.

6. Congenital Fistula of the Ear.

This condition represents an arrest in development of the first visceral cleft. Just in front of the tragus a very small scab may be seen, and when it has been removed there will be brought to light the orifice of a narrow sinus which contains creamy pus. The history given by the patient is simply that of a feebly discharging sinus, which occasionally heals up for a short time and then breaks open again. Cases of this nature are comparatively rare. The only effective treatment is excision of the walls of the fistulous channel.

CHAPTER III.

DISEASES OF THE EXTERNAL AUDITORY CANAL.

1. Anatomical Considerations.

The outer portion of the external auditory canal, as already stated, is composed of an extension of the cartilag-

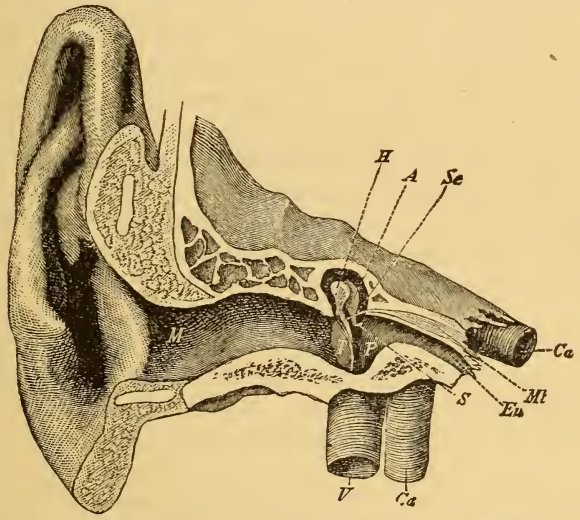

FIG. 21.—Anatomical Relations of External Auditory Canal, Middle Ear, etc. *M*, External auditory canal; *H*, hammer; *A*, anvil; *Se*, tendon of the tensor tympani muscle; *Mt*, tensor tympani muscle; *Eu*, Eustachian tube; *S*, stirrup; *P*, promontory, or inner wall of tympanum; *T*, membrana tympani; *Ca*, carotid artery; *V*, internal jugular vein. (After Hartmann.)

inous framework of the auricle. It is in this part, which represents about one-third of the whole canal, that the

greater number of the ceruminous glands are located. Throughout its inner two-thirds the canal consists entirely of a cylindrical mass of bone, lined internally with a thin, membrane-like layer of skin. This portion of the canal is spoken of indifferently as the osseous or the membranous external auditory canal. It is provided with nerves, lymphatics, and blood-vessels, but with very few glandular structures (ceruminous); these few being scattered along the upper wall of the canal, where the skin is somewhat thicker than elsewhere.

The relations of the external auditory canal to neighboring organs and structures are the following: Anteriorly, throughout the cartilaginous portion, the canal stands in close relationship to the parotid gland; throughout the osseous portion it forms the background of the temporomaxillary articulation. No organs of any special importance are located directly beneath the bony wall of the canal. On the other hand, the air-containing cells which communicate with the tympanic cavity proper or with the mastoid pneumatic spaces, stand in very close relationship to the posterior and upper osseous walls of the canal throughout their entire length.

2. Pathology.

Fundamentally, the diseases which are encountered in the external auditory canal are the following: Those which are of such a nature that they may occur in the skin of any part of the body (as, for example, an eczema or a syphilitic new growth); those which depend upon certain anatomical structures peculiar to the skin in that particular part of the body (as, for example, impacted cerumen); and, finally, those which originate in the neighboring bone structures and then later involve the cutaneous walls of the auditory canal.

3. Impacted Cerumen.

This is doubtless the commonest of all the affections of the auditory canal. When the cerumen first escapes from the mouths of the ceruminous glands it is a transparent, yellowish fluid. When it is not secreted too rapidly it soon becomes inspissated and assumes a darker color. For the further propulsion of this material out of the canal, Nature seems to have made a very curious provision. It is now an established fact that at least the uppermost layer of epithelium which lines the external auditory canal moves constantly from within outward. Here, therefore, is a force which is quite sufficient for the gradual extrusion of all ordinary accumulations of cerumen. In exceptional cases, however, this force fails to extrude it with sufficient rapidity; and then we are obliged to assume, first, that the amount of material secreted is excessive, and, second, that some obstacle exists which favors its becoming piled up into a mass the size of which is limited only by the capacity of the auditory canal. The sharp bend which the canal makes near the external orifice is often associated with such a marked shortening of one of its diameters that for all intents and purposes the canal is very much narrower at this point than it is at a short distance deeper in, where a large part of the cerumen is secreted. When the canal is thus narrowed at its outlet, it is easy to understand how this narrowing may permit the rapidly accumulating cerumen to become impacted.

The excessive secretion of cerumen is almost invariably associated with a catarrhal condition of the naso-pharyngeal mucous membrane. This relationship suggests the belief that the excessive activity of the ceruminous glands is a reflex phenomenon dependent primarily upon the inflammation that is going on in the vault of the pharynx.

In a few cases the glandular activity is so great that the

cerumen flows from the orifice of the auditory canal in the form of a somewhat thickish yellow fluid. Then again, in another series of cases, the glands cease altogether to secrete cerumen—a condition which suggests the likelihood that a stage of atrophy has followed that of hypersecretion.

Eczema is another condition which is apt to be associated with that of impacted cerumen.

Symptomatology.—Complete occlusion may take place so gradually that the patient's attention is attracted to only one symptom, viz., the gradual diminution of the hearing.

In many cases, however, the diminution of the hearing takes place suddenly, as after washing the head, or after a general bath, or after an attempt to clean the ear with the end of a towel. Tinnitus—subjective noises in the ear—and a sense of fulness in or pressure upon the ear, are also sometimes mentioned as symptoms.

Diagnosis.—Inspection with the speculum and reflected light reveals the presence, in typical cases, of a black or dark-brown mass, filling the canal and obstructing the view of the deeper parts. Until the contents of the canal have been thoroughly removed, it is not safe to say positively that the case is simply one of impacted cerumen.

Prognosis.—The prognosis, as regards the restoration of the hearing power, must always be guarded; for in many cases it will be found that the impacted cerumen has little or nothing to do with this impairment.

Treatment.—If the surgeon has a steady hand and can manage the illumination of the canal satisfactorily, his best course will be to remove the impacted mass by means of the curette and angular forceps. On the other hand, if he feels doubtful about his ability to accomplish the work in this manner, his best course will be to employ syringing with hot water. (See remarks on this subject in section 14 of Chapter I.)

In certain cases a preliminary softening may facilitate

the task of removing the mass. For this purpose either a strong solution of sodium bicarbonate or the liquor potassæ may be employed to advantage. The very prevalent practice of using olive oil as a means of softening hardened wax, is not to be commended.

4. Diffuse Inflammation.

There are three different types of diffuse inflammation of the external auditory canal, viz.:

(*a*) Those cases in which a direct irritant, applied to the skin of the canal, has excited the inflammation.

(*b*) Those in which the irritation has come from within the patient's system (either by way of the blood or through the nervous channels).

(*c*) Those in which the outward inflammation is simply an expression of an underlying chronic osteitis (the product of some earlier severe inflammation of the middle ear).

Of these three groups, practically only the last two are encountered in practice; for it rarely happens that an irritating substance is introduced from without into the external auditory canal. On the other hand, the cases which belong in the second group are very numerous, for the external meatus is one of the spots in the human body where eczema oftenest shows itself. Finally, if we exclude from the third group all those cases in which the diffuse inflammation of the canal is merely one of several phenomena that occur in the course of an acute inflammation of the middle ear and communicating pneumatic spaces, there will be left only a small number in which the diffuse inflammation of the canal still maintains a certain measure of independent force and merits the title of a chronic periostitis of this channel.

Physical Characteristics and Course of the Disease.—A diffuse inflammation of the external auditory canal presents itself under a variety of forms. The simplest of these is

that which is characterized by a diffuse redness and swelling of the skin lining the canal. These alterations may be limited to a fairly well-defined area or patch; or they may extend over one-half of the canal—either the entire cartilaginous or the entire osseous portion (including or excluding the outer surface of the tympanic membrane); or, finally, they may involve the entire canal. In one series of cases, the redness and swelling—accompanied or not, as the case may be, by some secretion from the inflamed skin—constitute the only recognizable alterations. In another series, the inflamed skin may show a strong proliferative tendency, which manifests itself by the development of granulation-tissue, and which, in rare cases, is associated with inflammation of the adjacent bone structure. And, finally, in a third series, a desquamative process may constitute the most striking feature of the disease.

In adults a diffuse inflammation of the external auditory canal is very apt to be a chronic affection; and even when it seems to have disappeared, either spontaneously or under the employment of suitable therapeutic measures, it is very apt to return again.

Diagnosis.—There is no difficulty whatever in recognizing the red, swollen, and perhaps moist condition of the skin lining the external auditory canal. We can then say positively that a diffuse otitis externa exists. If the drum-membrane presents at the same time a normal, or at least a non-inflamed condition, we can, with considerable confidence, make the diagnosis of a *primary* inflammation of the osseous portion of the canal. The question of its *acute* or *chronic* nature can only be determined after we have heard the history of the case; and even then we may readily be misled, as patients are often not aware of the existence of a chronic or subacute otitis externa diffusa until their attention is called to it by the pain or sense of fulness caused by an acute exacerbation of the inflammation. The point,

however, around which the greatest interest centres, is the condition of the middle ear in many of these cases. The drum-membrane being red and swollen, we naturally ask ourselves the question: Is the diffuse inflammation of the auditory canal merely an extension of that which is apparently going on in the middle ear? or, Is the membrana tympani, by virtue of the intimate relations existing between its outer layer and the skin of the osseous portion of the canal, involved secondarily in an inflammation which really began in this latter region? This question cannot be determined by inspection alone. We must test the hearing, examine the condition of the naso-pharyngeal mucous membrane, and ascertain, by auscultation, during the act of inflation, the condition of the middle ear and Eustachian tube. If there is comparatively little disturbance of the hearing, if there is no evidence of an acute naso-pharyngeal catarrh, and if the air enters the tympanic cavity freely and without râles or crackling sounds, we are fairly justified in pronouncing the disease an acute primary diffuse inflammation of the external auditory canal.

In those rare cases in which the inflammation begins in the skin of the external auditory canal and slowly spreads to the surrounding bone structures, the task of making a correct diagnosis may prove to be exceedingly difficult; and this is particularly likely to be the case if one is called to examine a patient for the first time after the osteitis has already become pronounced. Under such circumstances it would certainly not be strange if the error were made of mistaking the disease for a genuine mastoid inflammation of middle-ear origin.

Prognosis.—A primary diffuse inflammation of the external auditory canal may give rise to considerable discomfort, but it rarely, if ever, threatens serious consequences. It is only when we are called upon to state the probable duration of the disease, in any given case, that we must give a

very guarded prognosis. This is especially necessary in the markedly desquamative cases of long standing, the outlook here being at best very uncertain. In the more recent cases, and especially in those in which the desquamative tendency is less marked, we may encourage the patient to expect a decided amelioration, if not a positive cure. It must be remembered, however, that relapses are very common. In the proliferative forms of the disease, and especially in those cases in which the contiguous bone becomes involved in the inflammation, very great caution must be exercised in predicting what will be the ultimate outcome of the trouble.

Treatment.—The local management of this disease must vary according to the stage or condition in which it happens to be at the time. Thus, for example, if pain is a prominent symptom—which is only rarely the case—the hot douche will be found very effective in allaying it. If a fluid secretion has begun to escape from the canal, the proper procedure is to employ one of the astringents; and of these, the best, in my experience, is easily silver nitrate. This remedy should be employed, under these circumstances, in the form of solutions of different strengths. Before applying such a solution to the inflamed canal, it is advisable to first cleanse the latter thoroughly with warm water; then afterward, by means of a dropper, the silver-nitrate solution, of the desired strength, may be introduced into the canal. If the skin is unbroken, a strength of 120 grains to the ounce will answer well; but if the tissues are soft and moist—that is, if they are already beginning to granulate—one of 60 grains to the ounce will be found sufficiently strong. As soon as the solution causes a distinct sensation of warmth, or a stinging sensation, it should all be removed from the canal by means of a syringe and warm water. An ointment of a non-stimulating character should then be applied freely to the walls of the canal; and

the patient should be instructed to use the same ointment two or three times a day at home. After two or three days have gone by it will be possible to determine just how much or how little good has been accomplished by the application of the silver solution. According to the nature of this result, a repetition of the procedure may or may not seem desirable. In some instances it soon becomes apparent that this or any other stimulating application only serves to increase the irritation in the auditory canal. When this proves to be the case, all active interference with the seat of inflammation should be abandoned, and only soothing measures (warm douching, application of ointments) should be employed. It is in cases like this that we must place our chief dependence upon the constitutional treatment (diet; exercise; Carlsbad salts, etc.).

5. Growth of Aspergillus in the External Auditory Canal.

It is doubtful whether this fungus ever takes root and develops in a perfectly normal external auditory canal. In almost every instance it is possible to verify the fact that a diffuse inflammation of the skin of the canal antedates the development of the aspergillus. In these cases, therefore, we are dealing with one of the complications of a diffuse otitis externa.

The cases in which the parasitic growth is most frequently observed are those in which the diffuse inflammation is characterized by just enough secretion to keep the parts moist, but not enough to give rise to a current. The conditions which are present under these circumstances—viz., moisture, absence of motion either in the fluid secreted or in the surrounding air, a certain degree of darkness, and probably also a little decomposition of the organic materials contained in the secretion—are precisely those which are favorable to the further development of these germs, which are doubtless present at all times in the air of our houses.

The black and the white varieties of the aspergillus are generally both present at the same time in the external auditory canal, but the latter predominates in a very marked degree. To the naked eye the appearance is as if the lower wall of the canal, and often the outer surface of the membrana tympani also, were covered with a white, fuzzy material like cotton, interspersed here and there with black dots. Under the microscope the fungus—at least the white variety—presents the appearances shown in Fig. 22.

FIG. 22. — Aspergillus from External Auditory Canal. *M*, Mycelium; *H*, hypha; *S*, spores; *St*, sporangium; *G*, gonidium. (After Urbantschitsch.)

It is only in exceptional cases that the prognosis and treatment of a case of diffuse inflammation of the external auditory canal require to be changed to a material extent by reason of the presence of this complication. The strong silver solutions do good work in destroying those portions of the fungus which penetrate into the living tissues, and the free use of one of the antiseptic powders now so much employed in otological work (aristol, nosophen, dermatol, etc.) will prevent any new germs from securing a foothold.

6. Circumscribed Inflammation; Furuncles.

The external auditory canal seems to possess a special predisposition to furuncular inflammation. Our knowledge of the causes which give rise to the disease is rather limited. An irritating discharge from the middle ear, or from the deeper parts of the meatus (as, for example, in eczema), very often leads to the formation of furuncles in the outer or cartilaginous portion of the canal. It has also been observed that the disease is sometimes encountered in persons whose general health is not quite up to the proper standard. In a very large proportion of the cases, however, it will be found that furunculosis and a diffuse eczema of the external auditory canal go hand in hand; the latter seeming to be the necessary antecedent of the former.

Some authorities maintain that a circumscribed or furuncular inflammation is caused by micro-organisms—particularly the staphylococcus. This is undoubtedly true, in the sense that without the intervention of these organisms a furuncle could not develop; but it is scarcely true in the sense that staphylococci, for example, are able, under all circumstances, if permitted to gain entrance into a ceruminous or a sebaceous gland, or into a hair follicle, to set up there a furuncular inflammation. There are good reasons for believing that these bacteria easily gain an entrance into these parts of the body at all times, and yet many human beings pass through life without ever experiencing a furuncular inflammation of the external auditory canal. It is plain, therefore, that the determining etiological factor in these cases is not the presence of certain kinds of bacteria in the skin of the meatus, but a certain something else, which we can only vaguely designate by such terms as "diminished power of resistance on the part of the tissues," or "alteration of the tissue-juices in such a manner as to

rob them of their defensive powers in the presence of certain bacteria."

Furuncles of any considerable size are encountered only in the cartilaginous portion of the external auditory canal. They probably originate in the sebaceous or the ceruminous glands, which are very large and very numerous in this region. The base of the tragus, on the anterior wall of the orifice, is a favorite seat. In the osseous portion of the canal there are very few and very small ceruminous glands, situated chiefly along the upper wall, and, consequently, the furuncles encountered in this part of the ear are very small and insignificant. If a larger abscess is seen in this part of the ear, we may justly suspect that it is connected with disease of the adjacent bone, or with a sinus passing through the soft parts which lie above the drum-membrane.

Course of the Disease and Symptomatology.—Furuncles, as a rule, develop gradually. The patient first notices a little pain in the region of the ear, and, on pressing with his finger upon the parts, finds that they are slightly tender. Gradually the pain increases in severity, and the ear feels full and heavy. Deafness is not observed until the tumor reaches such a size that the meatus is closed at the point involved. The motions of the jaws are apt to cause pain, and in some cases there is well-marked œdema in the neighborhood of the affected ear. Rupture of the abscess may take place spontaneously as early as on the second day, but, as a rule, we must not look for this event before the third or fourth day. Healing and subsidence of all inflammatory symptoms usually soon follow. In those cases in which the cartilage seems to be involved, the abscess may go on developing for a week or longer. The whole course of the disease in these cases is much more protracted, and a depressed scar may remain after the parts have healed.

Diagnosis.—The important thing to ascertain, at least in some of these cases, is whether the swollen and tender con-

dition of the skin lining the external auditory canal is due to a furuncular inflammation of strictly local origin, or whether it represents an extension of inflammatory action from the middle ear to the soft parts of the auditory canal. In probably the majority of cases the local picture which this canal presents alone suffices to settle this question. But in a few instances this local picture is not so easily interpreted,—chiefly because the tender and swollen condition of the external orifice of the canal will not permit the surgeon to obtain a view of the tympanic membrane. When this is the case, he will have to depend largely upon the account, which the patient may give, of the order in which the different symptoms have succeeded one another. In the case of a furuncle, the pain and tenderness will precede the development of tinnitus and deafness; whereas if the inflammation starts first in the tympanic cavity and only afterward involves the soft parts of the auditory canal, the tinnitus certainly, and probably the deafness also, will precede the tenderness on pressure. The time when the pain develops differs in the different cases of both diseases, and consequently cannot be depended upon as an aid to differential diagnosis.

In a few cases, what seems at first to be a furuncular inflammation of the outer portion of the canal proves, later, to be a localized chondromalacosis. The more decided severity of all the symptoms, the greater depth to which the probe may be made to penetrate after the abscess has ruptured, the longer duration of the course of the disease, and the necessity, oftentimes, of cauterizing the abscess cavity with strong nitric acid before we can cause it to heal; all these facts, it seems to me, justify the view that we are dealing with something more profound, more destructive, than a simple furuncular inflammation.

Prognosis.—A simple furuncular inflammation never threatens serious consequences of any kind. On the other

hand, it is perhaps advisable—especially if we are dealing with a case of chronic eczema of the canal—to warn the patient that other furuncles may follow the first one.

Treatment.—The most urgent indication in this disease is to relieve the patient's suffering. It is not entirely clear how this may best be accomplished. Some authorities strongly advise the early employment of the knife. Wilde, on the other hand, gives the following advice: "As soon as we believe matter is formed and come some way to the surface, but not till then, we should make an incision." In most parts of the body, when the skin and subcutaneous connective tissues are incised, the opposite edges of the resulting wound show a more or less marked tendency to separate—the wound gapes. Owing partly to the denseness of the tissues in the outer portion of the external auditory canal and partly to the fact that they form the lining of an unyielding cylinder, no such gaping of the wound can take place; and this, as I believe, is the chief reason why the relief afforded by even a deep and fairly long incision so often fails to afford any appreciable degree of relief. In view of these facts, therefore, it is advisable to wait until the furuncle opens by natural processes; and, as a means of hastening these, and also for the purpose of mitigating the patient's suffering in the mean time, hot flaxseed meal poultices should be applied to the affected ear. After the abscess has broken, it is a good plan to douche the swollen canal, two or three times a day, with as hot water as the patient can comfortably bear, and then to apply to the parts, from time to time, some simple, non-stimulating ointment.

7. Syphilitic Disease.

Syphilitic manifestations are rarely encountered in the external auditory canal. Ulcerations, papillomatous or wart-like growths, and gummata are the forms in which the disease manifests itself in this region. These lesions,

in the few cases which I have seen, were located close to the outer orifice of the canal. Their physical appearances, their behavior under treatment, etc., differed in no important respect from the same conditions as they are observed in other parts of the body. It will therefore not be necessary to repeat all these details in the present place.

8. New-Growths.

The commonest form of new-growth in the external auditory canal is the *osteoma*. The development of new bone-tissue takes place both in the form of an exostosis (an outgrowth having a comparatively narrow base), and in that of a more diffuse hyperostosis or mound-like increase of the bone-substance. In some instances the irritation supplied by the constant flow of a purulent fluid from a chronically inflamed middle ear, over the skin (*i.e.*, the periosteum) of the auditory canal, affords an explanation of how the new-growth of bone came into existence. The etiology of most of these bony new-growths, however, is still largely unknown.

FIG. 23. — Exostoses nearly Filling the Lumen of the External Auditory Canal. (After Gruber.)

Aside from their power to interfere with the free escape of a discharge from the middle ear, or to diminish the hearing by occluding the channel through which sound reaches that particular ear, these bony growths are harmless. When, however, they are producing either of the evils mentioned, they should be removed; and the only way in which this can be effected is by operative interference. In some cases it is practicable to remove the bony growths by means of a narrow-bladed chisel and the mallet, while in others it will be found easier to first drill through the base of the exostosis and then to effect the final separation by means of the chisel and mallet.

The other new-growths observed in the external auditory canal—*carcinoma*, *sarcoma*, and *myxo-fibroma*—are so rarely encountered that it will be sufficient if I merely mention the fact that they sometimes develop primarily in this part of the ear.

9. Wounds and Other Injuries.

Injuries of the external auditory canal are of comparatively rare occurrence. In only one respect does a wound of the skin in the auditory canal—and I have reference more particularly to its cartilaginous portion—differ from a wound of the same character and extent in almost any other part of the body. I refer to the fact that the bleeding from the wound—as regards both the amount of blood and the duration of the flow—is out of all proportion to the extent of the injury. A small punctured wound inflicted by a broken twig sometimes bleeds, in a continuous trickle, for two and even three days. This peculiarity is undoubtedly to be attributed to the fact that those blood-vessels which pierce the cartilaginous framework, as many of them do, are not capable of contracting and retracting beyond a very limited extent; their physical relations being essentially the same as those of the blood-vessels which traverse bony structures.

In order to arrest the bleeding, in a case of this character, it is generally sufficient to apply a piece of styptic cotton firmly to the point from which the blood escapes.

The thin plate of bone which separates the external auditory canal from the temporo-maxillary joint, has, in rare cases, been fractured by a kick of a horse against the chin, or by a fall upon this part of the face.

10. Foreign Bodies.

If we exclude such bodies as sequestra of bone, hardened masses of cerumen, and aggregations of epithelial, cheesy, or calcareous materials, we may say that foreign bodies in

the external auditory canal are not of frequent occurrence. In the case of children these bodies usually comprise such objects as pebbles, beads, small buttons, beans, grains of corn, pieces of lead from a lead-pencil, small rolls of paper, etc. In adults, a forgotten mass of cotton-wool is sometimes found impacted in the inner half of the meatus, or a stiff piece of hair may be found sprung like a bow between the wall of the canal and the membrana tympani. Living objects—such as a fly, a cockroach, a Croton bug, a bedbug, or the larvæ of the house-fly—are also sometimes found in the auditory canal.

Hard substances, like beads, pebbles, or buttons, if they do not cause pain, and if they are not actually impacted in the auditory canal, may be allowed to remain there undisturbed for a reasonable length of time. In one of my cases, for example, a glass bead of large size had remained twelve years in the canal without doing the slightest damage that I could discover. As the foreign body, however, may change its position and become wedged in between the drum-membrane and the anterior wall of the canal, and as an intercurrent inflammation of either the meatus or the middle ear might be seriously complicated by the presence of such a foreign body in the canal, it is better not to delay its removal any longer than is necessary to insure a successful result. If the body is impacted in the canal and is causing pain, the sooner it is removed the better. If the operation is postponed, the outer portion of the canal may become swollen, and the task of extracting the foreign body may thereby be rendered materially more difficult. In the case of substances like dried peas and beans, which may swell up in water to fully twice their original size, it is important to abstain from using the syringe; or else, if we fail by means of it to remove a foreign body of this nature, we should proceed, without further delay, to extract it by means of instruments.

Treatment.—Small bodies, which simply lie in the canal without being impacted between its walls, may be removed by means of such instruments as the slender forceps, the curette, or a bent probe, or by means of the syringe and warm water. If the foreign body is of sufficient size to fill the canal, or to press against its sides at two or more points, the use of the syringe seems to me to be thoroughly irrational and unpractical. What is required in such a case is a "force from behind," and not one that spends itself upon the outer surface of the foreign body, and thus tends to drive it deeper down into the canal. If the shape and position of the body are such that we may with some degree of confidence hope to extract it by seizing it directly with the slender forceps, this plan may be adopted. But it is far better not to make such an attempt, unless we are quite confident of success; for if we lose our grasp upon the body, we may be almost sure that we shall drive it a little beyond the position which it previously occupied, and thus render the problem of removal correspondingly more difficult. The better plan is to explore the circumference of the foreign body with the probe, or with a small smooth-edged curette, and thus ascertain whether there is not some point where it is separated by a certain amount of space from the wall of the meatus. This is the point at which we should introduce the instrument by means of which we intend to bring the desired *vis à tergo* to bear upon the foreign body. In the case of a roundish body like a cherry-pit, a pea, or a bean, we shall undoubtedly often fail to find such a point. Under these circumstances, if we desire to bring a similar force to bear upon the impacted body, we must employ an instrument that is both slender and strong: slender enough to force its way between the foreign body and the skin of the canal without injuring the latter, and yet strong enough, after it has once been pushed inward the requisite distance, to exert a decided downward and outward pressure upon the

inner end of the mass. A small-sized, round-edged curette and a delicately constructed steel hook are the instruments best adapted for this sort of work. In introducing the curette, which must first be slightly bent flatwise, we must make its ring-shaped end describe an arc of a rather small circle, or we shall cause the patient unnecessary pain, and perhaps fail to carry the end of the instrument beyond the foreign body. In introducing the hook we must follow a somewhat different principle: as in the case of the curette we must introduce it flatwise, but as we push the instrument farther and farther inward, we must make the end of the hook proper hug the foreign body constantly. By pursuing this plan we shall know instantly when the instrument has reached the inner end of the foreign body; for the hook, no longer meeting with the resistance offered by the side of the obstructing mass, will at that very moment perform the rotatory movement which the pressure of our fingers has tended to give it. We must not allow it, however, to perform more than a quarter of a turn, for fear of bringing the free end in contact with the walls of the canal. When the hook has performed this quarter revolution, we should withdraw it cautiously but firmly, and thus dislodge the impacted foreign body.

The after-treatment in the graver cases is based upon the same principles as those which govern the treatment of other acute inflammations of the canal or of the middle ear. In the simpler cases no after-treatment whatever is required.

CHAPTER IV.

METHODS OF EXAMINING THE MIDDLE EAR.

While the symptomatology furnishes us with valuable information in regard to the probable nature of the pathological changes which are going on in the middle ear, in any given case, it is nevertheless necessary to supplement this with evidence of a more positive character. This evidence can be obtained by a direct inspection of the tympanic membrane and adjacent walls of the auditory canal, by auscultation of the sounds produced while air is being forced into the middle ear through the Eustachian tube, and by inspection and palpation of the skin in the immediate vicinity of the auricle.

1. Direct Inspection of the Tympanic Membrane and Adjacent Walls of the Auditory Canal.

In a few cases the external auditory canal is so large and so straight that a view of the membrana tympani may be obtained by direct illumination and without the aid of a speculum. In the great majority of instances, however, it will be found necessary to employ the latter instrument and reflected light. By means of such simple inspection we may generally obtain all the information that is required in regard to the texture, degree of vascularity, position, etc., of the tympanic membrane. Now and then, however, some doubt is likely to arise in the mind of the observer in regard to the correct interpretation of parts of the picture presented to his eye. When he experiences this uncer-

tainty he should ascertain how the lesions in question behave when they are touched and handled, so to speak, with the probe or the curette, and when they are subjected to the influence of air forced into the tympanic cavity by way of the Eustachian tube, or to alternate rarefactions and condensations of the air in the external meatus. As regards the *probing of the drum-membrane* and adjacent parts under illumination, very little need be said. Inasmuch as the eye of the observer is watching the effects of the instrumental manipulations, no possible harm can be done to the ear. The amount of discomfort caused by such manipulations is very slight, provided they be performed with reasonable gentleness. The Valsalva's experiment, described elsewhere, affords the simplest and most convenient means of inflating the middle ear when it is desired to watch the behavior of the tympanic membrane under the influence of a pushing force exerted from within. But if, as sometimes happens, air cannot be forced in this manner into the middle ear, it will be necessary for an assistant to inflate the cavity either by means of Politzer's method or by aid of the Eustachian catheter. When it seems desirable to rarefy the air in the auditory canal, in order that the observer may have the opportunity of witnessing the behavior of the drum-membrane when moved alternately outward and inward, Siegle's pneumatic speculum must be employed. This instrument (Fig. 24) consists of a central cylindrical chamber (about an inch and a half in diameter and two inches in length), of either metal or hard rubber, to which is attached a flexible rubber tube about one foot in length. To one end of the chamber a conical speculum is fitted; the opposite end is closed by a glass plate which is placed at such an inclination to the axis of the cylinder that the rays of light used for illuminating the drum-membrane may readily pass through it without any portion of them being reflected back to the eye of the observer. The free end of

the speculum should be sheathed with soft-rubber tubing, in order that it may fit air-tight in the auditory canal. When the instrument is in actual use the observer, by holding the free end of the rubber tube in his mouth, has it in his power to condense or rarefy the air in the auditory

Fig. 24.—Siegle's Pneumatic Ear Speculum. (The speculum is reduced to about ⅔ and the rubber bag to ¼ the natural size.) (After Politzer.) (Many persons prefer to dispense with the rubber bag altogether. In that case the free end of the connecting piece of rubber tubing is held by the observer in his mouth, and the required exhaustion of the air in the air-tight speculum is effected by suction.)

canal, and, while doing so, to watch the effects of these procedures upon the drum-membrane and handle of the malleus.

2. Valsalva's Method of Inflating the Middle Ear.

In inflating the middle ear by this method the patient closes both nostrils by grasping the nose with the thumb and forefinger of one hand, shuts his mouth firmly, and then makes a strong expiratory effort. In this way he compresses the air in the pharyngeal and nasal cavities to such an extent that it seeks an outlet through the Eustachian tubes. If the effort is successful, the physician, who has previously established a communication between

his own ear and that of the patient, by means of a flexible auscultation tube, will hear a slight puff or thud, as the air enters the middle ear and distends the drum-membrane. Of the three methods at our command, this is altogether the most unsatisfactory, at least for the purposes of auscultation. When, however, it is desired to observe the changes that take place in the tympanic membrane while air is being forcibly introduced into the middle ear, Valsalva's method is undoubtedly more convenient than either Politzer's or that which requires the employment of the Eustachian catheter. For therapeutic purposes, as will be explained in the next section, Valsalva's method should be omitted altogether from the category of therapeutic agents.

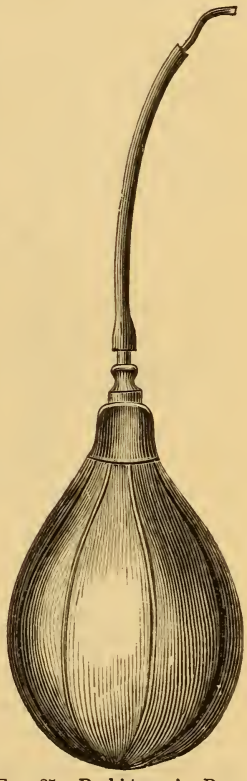

Fig. 25.—Politzer's Bag. (Nearly ½ the natural size.)

3. Politzer's Method of Inflating the Middle Ear.

The apparatus which is ordinarily used in carrying out Politzer's method of inflation consists of three parts, viz., a rubber bag, provided at one end with a hard-rubber nozzle, and of such a size and shape that it can readily be grasped with the hand; a short piece of rubber tubing, of such a small calibre that the nozzle of the bag will fit it tightly; and, lastly, either a curved cylindrical or a bulbous nose-piece. The bag (Fig. 25), which is made of soft black rubber, is pear-shaped and ribbed

longitudinally at intervals of about one inch. A curved, cylindrical nose-piece, of hard rubber, is that which is best adapted for use in adult patients (see Fig. 26). In children under four or five years of age, in whom the

FIG. 26.—Nose-piece of Politzer's Apparatus. (Natural size.)

nasal orifice is quite small and tender, a nose-piece consisting of a cone-shaped (almost spherical) glass bulb will usually be found preferable to the cylindrical one.

The mode of procedure, in Politzer's method, is the following: The patient is told to take a little water into his mouth and to hold it there, with closed lips, until the physician says, Swallow! At this signal he should forthwith swallow the water. The physician, on his part, is to hold the bag in his right hand, and then, as soon as the patient has taken the water into his mouth, he is to introduce the nose-piece into the patient's left nostril, using, if necessary, the left hand to aid him in accomplishing this. When the nose-piece of the instrument is in its proper position on the floor of the nasal passage, the physician should at once compress the nostrils over the rubber nose-piece, and give the

FIG. 27.—Proper Method of using Politzer's Inflation Apparatus. (After Politzer.)

patient the signal to swallow. The act of compressing the bag and forcing air into the nasal cavities should follow the signal almost instantly—that is, at the precise moment when, in the act of swallowing, the thyroid cartilage makes an upward movement. (Fig. 27 shows the position of the physician's hands at the moment when he gives the patient the signal.)

Certain precautions should be mentioned here. In the first place, the middle ears should never be inflated by this method until after an examination has demonstrated the fact that both tympanic membranes are in a sufficiently strong condition to bear the sudden strain from within. In the case of young children the pressure exerted upon the bag should always be less than that employed for an adult. In the third place, instruct the patient to take very little water into his mouth; a teaspoonful is sufficient. Finally, if we wish to spare our patient unnecessary pain or the discomfort of a nose-bleed, it is necessary that we should introduce the nose-piece of Politzer's apparatus with some degree of care. The large conical glass nose-piece can scarcely be used in such a clumsy or rough manner as to cause either pain or nose-bleed; but the curved, cylindrical, hard-rubber instrument is very well adapted to cause both, unless introduced gently, and in one particular way. Thus, for example, in each nasal orifice there is but one spot where the instrument can properly be allowed to remain while the nostrils are firmly compressed over it, viz., on the floor of the canal, as far as possible from the median plane (the septum narium). In this position, the instrument, if it has not been pushed in too far, will cause very little discomfort. If the nose-piece is properly curved, it is an easy matter to avoid the danger of pushing it in too far, by always allowing the straight portion of the instrument to rest against the patient's upper lip, in the direction of a line running

from the outer angle of the nasal orifice to the outer angle of the mouth.

The device of having the patient swallow a little water at a given signal can scarcely be resorted to in children under four years of age. In an infant it is simply necessary to adjust the glass bulb to one nostril, and then, while the other is kept closed by a finger of the same hand that holds the bulb in position, to compress the bag. It makes no difference whether the child's mouth is open or shut; the inflation seems to succeed equally well in both cases. In children of three, four, or five years of age, it is often an easy matter to teach them to distend their cheeks at the moment the signal (blow!) is given. If pain or a sense of fulness in the ear is complained of immediately after the inflation, it is a good plan to let the child swallow two or three mouthfuls of water, in order to facilitate the escape of air that may have become as it were imprisoned in the middle ear.

Finally, the operator must not forget to give the nose-piece a thorough cleaning before he puts the instrument away. Under ordinary circumstances I always place this part of the instrument in scalding water; and whenever I use it upon a suspicious case I first place it in scalding water for a few moments and then allow it to remain for a longer time in a strong bichloride of mercury solution.

4. The Fundamental Differences between Valsalva's and Politzer's Methods.

In both of these methods the middle ears are inflated by compressing the air that is imprisoned in the nasal and naso-pharyngeal cavities to such a degree that it overcomes the resistance offered by the walls of the Eustachian tube, and forces its way into the tympanic cavity. There are two respects, however, in which these methods differ from each other very widely. In the first place, Valsalva's

plan necessitates a degree of venous congestion of the head and neck that is directly proportionate to the force used in compressing the air contained in the naso-pharyngeal space. It therefore promotes, in a certain measure, the very pathological condition which, in nine cases out of ten, constitutes the leading characteristic of the disease. (I refer to the paretic, that is, the dilated condition of the blood-vessels of the middle ear.) Then, in the second place, it furnishes no aid whatever—aside from mere air pressure—toward the opening of the tube itself. Indeed, as a matter of fact, by increasing the fulness of the blood-vessels, it tends to diminish the calibre of the Eustachian tube. Politzer's method, on the other hand, is not less efficient than that of Valsalva in compressing the air contained in the naso-pharyngeal space, while at the same time it is entirely free from the two objections which I have just mentioned. It produces no fulness of the blood-vessels nor does it diminish the permeability of the Eustachian tube; but, on the contrary, it makes the patient open that channel as widely as he can (by the aid of the muscles which naturally perform this task), just at the very instant when the compressed air in the vault is seeking an outlet through it in the direction of the middle ear.

5. Catheterization of the Eustachian Tube.

Eustachian catheters are made of German silver, of coin silver, and of hard rubber. As cleanliness is a very important matter, catheters of German silver should not be tolerated; for it is almost impossible to keep them thoroughly clean.

With regard to the curve which a good Eustachian catheter should have, I may say that the one represented in the accompanying cut (Fig. 28) is that which I have found suited to the great majority of adult patients. Some of my colleagues use a straighter instrument, and others one

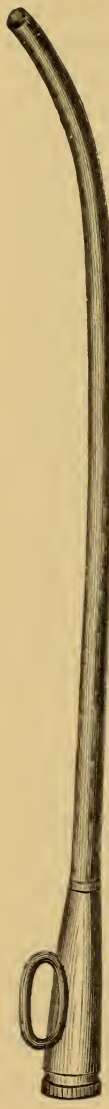

Fig. 28.—Eustachian Catheter. (Natural size.)

of even greater curvature; from which facts it is proper to draw the conclusion that the middle ear may be successfully inflated by variously curved catheters. To secure the most effective inflation, however, we should give the catheter such a curve that, when it is in position and air is forced through it, the direction of the escaping current will be the same as that of the Eustachian tube itself. The common error, so far as my observation goes, is to give the instrument a curve of too short a radius, which causes a large part of the force of the current of air to spend itself upon the upper wall of the Eustachian tube. In children from five to about twelve years of age, it will be found better to use a catheter that is even less curved than that represented in the cut; or one, at all events, in which the curve begins at a point considerably nearer the free end than is the case in this instrument.

The rubber bag used for inflating the middle ear according to Politzer's method answers equally well—after the piece of soft-rubber tubing has been removed—for inflating this cavity through the Eustachian catheter.

The different steps of the operation may be briefly described as follows:

The physician should sit directly facing the patient, and on his right hand, within easy reach, should be his rubber bag, auscultation-tube, and a bowl or goblet, partially filled with water and containing five or six catheters of different sizes and degrees of

curvature. He should have his forehead-mirror in position, ready for use, as he may at the very beginning find it desirable to examine, under illumination by reflected light, the patient's anterior nares. Everything being in readiness, the operator should place the fingers of his left hand firmly upon the patient's forehead, and with the end of his thumb he should elevate as much as possible the end of the patient's nose—the object of the latter procedure being to straighten the entrance to the nasal passage and in so far to facilitate the introduction of the catheter. This instrument should be held lightly by the physician, between the thumb and forefinger of his right hand, and at no time should force be used in overcoming any obstacles that may be encountered. Just within the nasal orifice, the floor of the nasal passage rises up in the form of a ridge, the inner or deeper side of which is more abrupt than the outer one. When the catheter is first introduced into the nasal orifice, its outer end should be at a somewhat lower level, though in some cases we may begin at once with the instrument in a nearly horizontal position. To pass it beyond the ridge, and engage it in the lower nasal passage, the physician must elevate the ring end of the instrument until it occupies a nearly horizontal position. It is at this stage of the operation that the beginner is very apt to make a mistake. Instead of

FIG. 29.—Showing how the Catheter is to be held in position firmly, and how the inflation bag is to be used in forcing air into the catheter. (After Politzer.)

passing the catheter along the floor of the nasal canal, he slips it over the upper surface of the inferior turbinated body, and, on approaching the naso-pharyngeal space, wonders why his efforts to turn the instrument into the mouth of the Eustachian tube cause the patient such great distress. A glance at the illustrations of this region, in some good treatise on anatomy, will show how easy it is to make this mistake. It is only necessary to push the beak of the instrument a short distance beyond the summit of the ridge, and we shall find it slipping only too easily along the wrong channel. When the catheter has been pushed beyond the ridge, and is actually resting upon the inferior turbinated body, the elevation of the ring end of the instrument will not correct the error unless the catheter be withdrawn a certain distance. In the first stage of the operation, therefore, it is important to hug the floor of the nasal passage with the beak of the catheter, at least until the instrument has passed beneath the inferior turbinated body, and is well engaged in the lower channel. As already stated, it is better, from this point onward, to let the instrument find its own way. By this I mean that if the catheter encounters some obstacles, we should abandon the attempt to push it onward in a certain fixed manner,—*i.e.*, with the beak always pointing downward and backward,—and should rotate the instrument slowly, while keeping up a gentle pressure from behind, until we find a position in which it no longer encounters opposition, but yields to the pressure which tends to drive it farther inward toward the naso-pharynx. As we wish the instrument, on first reaching that cavity, to lie with its beak turned directly downward, we should begin at once, after passing the obstacle referred to, to rotate the catheter back toward the desired position. If we fail in our efforts to overcome the obstacle encountered, we must either resort to an instrument of smaller diameter, or try to reach the Eustachian tube by

way of the nasal passage of the opposite side. The latter course will usually be found the preferable one. When the catheter is in the naso-pharyngeal space, with its beak turned directly downward, we should first make sure of our bearings by pushing the instrument onward until we feel

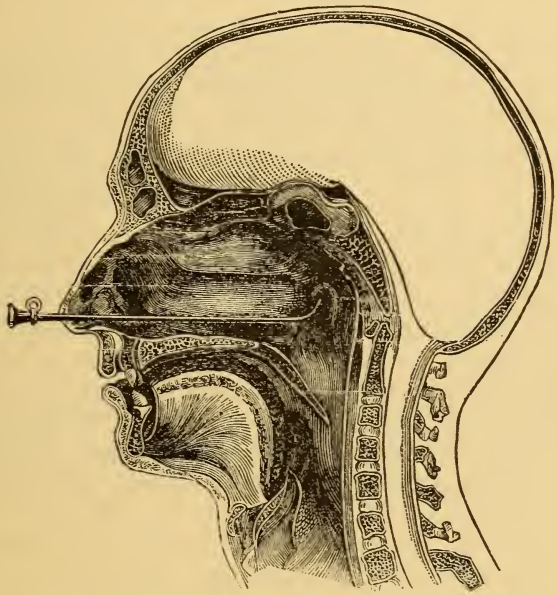

FIG. 30.—Eustachian Catheter in Position. (After Politzer.)

the resistance offered by the posterior pharyngeal wall. When the catheter is in this position, we know that if we rotate it far enough we shall carry the beak into what is known as Rosenmüller's fossa, a slight depression located just behind the mouth of the Eustachian tube. Hence, if we wish to introduce the instrument into the latter cavity, we must draw it back a distance of two- or three-eighths of an inch, and then rotate it through an arc of about one

hundred and thirty-five degrees (or until a line drawn through the plane of the ring attached to the catheter shall pass through the outer angle of the patient's eye). If we rotate the beak of the catheter first into Rosenmüller's fossa, and then draw it back a short distance, we can often feel the end of the instrument pass over the rounded eminence which constitutes the inner lip of the mouth of the Eustachian tube. As the distance of the tubal orifice from the posterior pharyngeal wall varies in different individuals, the method last described, of guiding our movements by aid of the sense of touch, rather than by rough estimates of distance, is the one to which most aurists, I think, give the preference. After the beak has been lodged in the mouth of the Eustachian tube the physician should grasp the body of the instrument with the thumb and forefinger of the left hand at a point as near as possible to the nasal orifice, while the other fingers of this hand are placed firmly on the bridge of the patient's nose (see Fig. 29).

After these various steps have been taken the physician should give the patient one end of the auscultation-tube to place in the meatus of the corresponding ear, and should fix the other end tightly in his own auditory canal, preferably the left one. With his right hand he should then grasp the rubber bag, and apply the hard-rubber nozzle of the instrument to the mouth of the Eustachian catheter. If the latter instrument is in the right position, and the Eustachian tube is not unnaturally contracted, he will hear the air streaming as it were into his own ear; and if, while he is thus inflating the tympanic cavity, the patient should perform the act of swallowing, the physician will suddenly notice a marked increase in the sound produced by the inrushing air—a phenomenon due to the sudden enlargement of the tubal channel. If the catheter, however, occupies a wrong position, he will probably still hear the air streaming out of the end of the instrument, but it will no longer

seem to be escaping into his own ear; the sound will appear to be more distant and less distinct.

In withdrawing the catheter from the nasal cavities, no special precautions are necessary. The instrument is first to be rotated back to its original position, with the beak pointing downward, and then it is to be withdrawn gently from the nose.

I should add here the statement that the necessity for employing catheterization, either for diagnostic or for therapeutic purposes, does not often arise.

6. Other Methods of Investigating the Condition of the Eustachian Tube.

In a large proportion of the cases a good view of the tubal orifice and adjacent parts can be obtained by means of the laryngeal mirror and reflected light. It is also sometimes possible to inspect these parts through what is termed a Zaufal's speculum—a long, narrow tube which is passed along the lower nasal passage until its distal end reaches the immediate vicinity of the tubal orifice. Finally, a very good idea of the condition of this region may be obtained by digital exploration, by way of the mouth.

CHAPTER V.

SKETCH OF THE ANATOMY AND PHYSIOLOGY OF THE MIDDLE EAR.

1. Relations of the Different Cavities which Compose the Middle Ear to One Another.

The middle ear is composed of several communicating chambers, of very irregular shapes, which are for the most part surrounded by solid bone. The most important of these is the tympanic cavity proper, which is located on the inner side of the tympanic membrane and communicates anteriorly with the naso-pharyngeal cavity—*i.e.*, with the outer world—by way of a long and narrow channel called the Eustachian tube. At its posterior end the tympanic cavity communicates with that of the mastoid antrum by a somewhat narrow passage called the *aditus ad antrum*. The antrum itself, which is about as large as a small pea, possesses

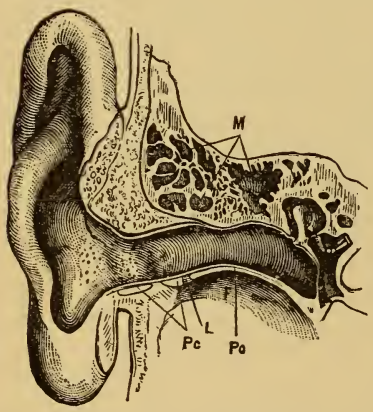

FIG. 31.—Transverse Vertical Section of the Temporal Bone, showing the relations of the external auditory canal to the middle ear, and of the ossicles to each other and to the membrana tympani and fenestra ovalis. (After Urbantschitsch.) *M*, Mastoid cells; *Pc*, cartilaginous meatus; *Po*, osseous meatus; *L*, membranous connection between the cartilaginous and the osseous portions of the canal; *F*, fossa of the temporo-maxillary articulation.

walls that are at nearly all points honeycombed with small pockets or channels leading into the countless air-containing spaces of the mastoid process and surrounding portions of the temporal bone.

All these different recesses and cavities are lined with a delicate mucous membrane, which only at one point—the mound-like entrance of the Eustachian tube—acquires a notable thickness. In the tube itself the cells on the surface of the mucous membrane (at least throughout its lower two-thirds) are of the ciliated columnar variety.

2. Boundaries of the Middle Ear.

(*a*) Superiorly, the cavities of the middle ear—or, rather, those of the tympanum and the antrum—are separated from the dura mater by a plate of bone which varies in thickness from perhaps half a millimetre to two millimetres. This plate is known as the *tegmen tympani et antri.* It possesses openings through which blood-vessels pass from the middle ear to the cranial cavity. Sometimes an actual deficiency of limited extent exists in the tegmen; thus permitting the dura mater and the tympanic mucous membrane to lie in immediate contact, the one with the other.

(*b*) Inferiorly, the tympanic and antral cavities are bounded by a comparatively thick mass of bone substance; the internal carotid artery being the only organ of importance which approaches (somewhat anteriorly) the floor of this double cavity.

(*c*) Anteriorly, the walls of the tympanum converge toward the mound-like mass of mucous membrane, in the centre of which is the orifice of the Eustachian tube.

(*d*) Posteriorly—that is, at the farthest end of the antrum—the cavity approaches quite closely (five or six millimetres) to the anterior wall of the sigmoid sinus—that

venous channel which, a short distance lower down, becomes the internal jugular vein.

(*e*) Various structures of importance are to be found in the inner wall of the tympanic and antral cavities. Low down and near the posterior end is the so-called *fenestra*

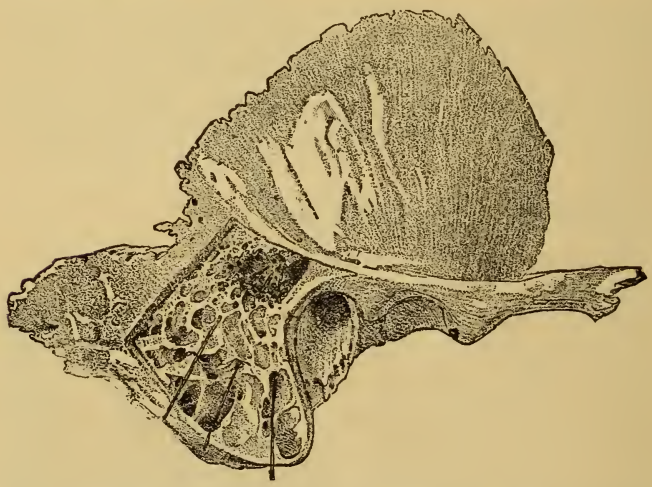

Fig. 32.—Dissection (by chiselling) of the Mastoid Process, showing the free communication which exists between the pneumatic cells in the body of the process and the antrum. The upper ends of the bristles may be seen projecting into the cavity of the antrum. (From Nuhn's Atlas of Surgical Anatomy; slightly reduced in size.)

rotunda, the niche at the bottom of which is set the secondary tympanic membrane. A short distance immediately above it is a second window, the *fenestra ovalis*, in which snugly fits the foot-plate of the stapes. Still higher up, but concealed within the substance of the bone, is the facial nerve. At this point it runs almost horizontally, but very quickly, after it has cleared the posterior limit of the oval window, it makes a downward bend and pursues a course very nearly at right angles to that which it follows after it first approaches the inner wall of the tympanum. Besides

the structures named, there are also, in this inner wall, the stapedius muscle, the tendon of the tensor tympani muscle (its belly lying along the inner side of the Eustachian tube), and the beginning of the first whorl of the cochlea.

(*f*) The larger part of the outer wall of the tympanic cavity is represented by the *membrana tympani.* In front of and behind this membrane the wall consists simply of bone tissue of a more or less cancellous character.

(*g*) The central part of the tympanic cavity is spanned by the chain of three ossicles — the malleus, the incus, and the stapes. These three little bones are so disposed that they virtually subdivide the tympanic cavity into an upper chamber (the epitympanic space, or the vault of the tympanum [1]) and a lower one.

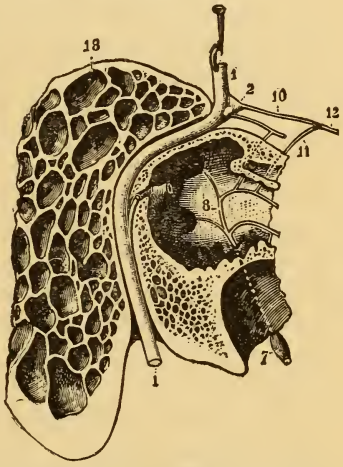

Fig. 33.—Diagram Showing the Relations of the Facial Nerve to the Different Structures of the Temporal Bone. (After Testut.) 1, 1, Facial nerve; 2, ganglion geniculatum; 7, petrous ganglion, or ganglion of Andersch; 8, Jacobson's nerve, crossing the inner wall of the tympanic cavity; 10, great superficial petrosal nerve; 11, great deep petrosal nerve; 12, cranial twig of the Vidian nerve, formed by the fusion of the two preceding petrosal nerves; 18, pneumatic cells of the mastoid portion of the temporal bone.

3. Blood-Supply of the Middle Ear.

(*a*) On its outer aspect the membrana tympani receives its blood-supply from the *auricularis profunda artery.* On the side toward the tympanic cavity it receives this supply partly from the *anterior tympanic artery,* a branch of the internal maxillary, and partly from the

[1] Called also by some the attic.

stylo-mastoid artery. The cuticular veins of the membrana tympani empty the larger part of their blood into the veins of the external auditory canal, but nevertheless they may —through certain branches which penetrate into the tympanum—pour it into the veins of that cavity. On the mucous surface of the membrana tympani the veins radiate from the periphery toward the manubrium, and, *vice versa*, from the central portions toward the periphery. Around the border of the membrane the venous trunks are clustered together in the form of a wreath. At various points perforating branches connect this venous circle with the similar one which exists on the cutaneous side of the membrane.

(*b*) The tympanic cavity is supplied with blood from as many as five different sources, viz., the stylo-mastoid, the middle meningeal, the ascending pharyngeal, the internal carotid, and the anterior tympanic arteries. The *stylo-mastoid artery*, itself a branch of the posterior auricular, gives off twigs which supply the mastoid region, the vicinity of the stapes, and the posterior end of the tympanic cavity. The *middle meningeal artery* (a branch of the internal maxillary) gives off three twigs: one for the tensor tympani muscle, a second (the superior tympanic artery) for the mucous membrane covering the upper part of the promontory, and a third (the ramus petrosus superficialis) which anastomoses with the stylo-mastoid artery. The *ascending pharyngeal artery* gives off twigs which supply the floor of the tympanic cavity, and the lower part of the promontory. The *internal carotid artery* gives off a branch, the ramus carotico-tympanicus, which supplies the anterior wall of the tympanic cavity. There is also another small twig which passes between the crura of the stapes on its way to the promontory.

Blood-vessels of the tympanic cavity anastomose with those of the labyrinth.

The mastoid cells are supplied with blood by branches of

the stylo-mastoid and middle meningeal arteries; the latter passing through the petro-squamous suture on their way from the cranial cavity.

The Eustachian tube receives its blood-supply from the ascending pharyngeal, middle meningeal, and Vidian arteries.

The veins of the tympanic cavity pour their blood into the middle meningeal vein, the pterygoid plexus, and the deep auricular vein. Minute veins also pass from the mastoid region (antrum and pneumatic cells situated farther back) to the superior petrosal and the sigmoid sinuses.

It will thus be seen that there are several pathways along which pathogenic micro-organisms may pass from the middle ear to the intracranial organs, and *vice versa*.

4. Peculiarities of Construction of the Membrana Tympani.

In the adult the drum-membrane should present a slightly pearl-gray color, and yet at the same time it should also possess a certain degree of translucency. The substantia propria, which forms the groundwork of the drum-membrane, is similar in structure to certain tendons and aponeuroses of muscles which present a gray or pearl-gray color, and it is not unlikely that this may explain, in large measure, the grayish hue of the normal tympanic membrane. In infants and young children this peculiar color is either lacking or is less well defined.

Over the outer surface of the membrane are spread, first, a thin layer of elastic tissue, capillary blood-vessels, lymphatics, and nerves, and then finally a pellicle of horny epithelial cells. Under normal conditions these superimposed structures offer very little obstruction to the passage of light, but a part of it is undoubtedly arrested by the substantia propria, and reflected back to the eye of the observer from its outer surface, thus producing the grayish appearance already referred to above.

From the processus brevis to its lower free end the manubrium mallei is as it were sheathed in the substantia propria, and forms therefore an integral part of the drum-membrane. Its outer surface is covered by soft parts (mainly epidermis) of exceeding thinness, and consequently under normal conditions it presents to the eye of the observer an appearance as if this piece of bone were entirely uncovered. The picture is that of a narrow white or whitish-yellow straight band running from the upper and anterior

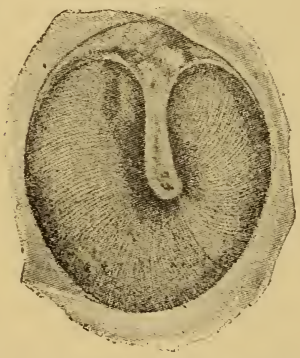

Fig. 34.—Normal Tympanic Membrane as Seen from the External Auditory Canal. (Very much enlarged.) In the posterior and superior quadrant of the membrane, a little to the left of the manubrium mallei, may be seen the shadowy outlines of the long process of the incus. (After Zuckerkandl.)

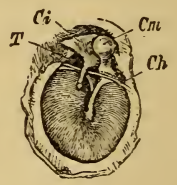

Fig. 35.—View of Inner Side of the Membrana Tympani, showing the course of the chorda tympani nerve between the malleus and the long process of the incus. (After Urbantschitsch.) *Ci*, Body of the incus; *Cm*, head of the malleus; *Ch*, chorda tympani nerve; *T*, inner fold of the posterior pocket.

limit of the membrana vibrans downward and backward to about the centre of the membrane. Probably in most cases the tip end of the manubrium will seem to be a little nearer to the anterior inferior than to the posterior superior periphery of the membrane. But for all practical purposes it is sufficiently accurate to describe this really central point as *appearing* to be equidistant from these two parts of the periphery.

The short process (or processus brevis) itself, as seen through the speculum by reflected light, looks like a tiny cone-shaped spur, whose base merges insensibly into the surrounding soft parts. Its color is precisely the same as that of the manubrium from which it springs.

In a normal state the outer surface of the drum-membrane is quite smooth; sufficiently so, in fact, for the light to be reflected from it in much the same manner as it ordinarily is from a polished surface of hard wood. By reason of the shape—that of the concave side of a shallow cone—and the inclination of the membrane, the area of reflected light always seems to have the same limits and to occupy the same position upon the membrana tympani. It is seen in the form of an isosceles triangle whose apex coincides with the tip end of the manubrium mallei, while its comparatively narrow base rests against the periphery of the membrane. It is technically termed "the bright spot."

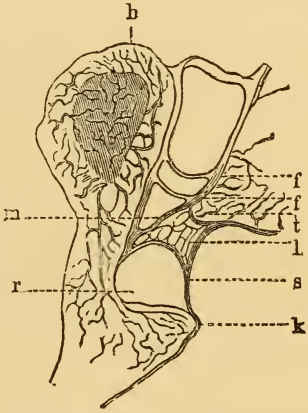

FIG. 36.—Longitudinal Section of the Malleus, showing the system of cavities or pockets lying between the head and neck of that ossicle and the drum-membrane. *h*, Head of malleus; *k*, short process; *s*, layer of skin toward external auditory canal; *r*, larger space situated just above the short process; *l* and *m*, smaller cavities. (After Politzer.)

Under natural conditions the region occupied by the membrana flaccida—Shrapnell's membrane—is not distinguishable from the neighboring skin-covered walls of the auditory canal by any special boundaries or differences in color or texture. The region in question lies directly above the processus brevis of the malleus, and its limits are the sides and top of

the arched notch in the squamous portion of the temporal bone.

The loose-meshed connective tissue which lies between the head and neck of the malleus and the outer wall of the epitympanic space (see Fig. 36)—the region of Shrapnell's membrane—is peculiarly adapted to become the seat of an invasion of pathogenic micro-organisms; and it is therefore no wonder that the malleus itself and even the adjacent wall of bone are, as a matter of fact, often invaded.

A very important function of the tympanic membrane, it must be remembered, is that of protecting the delicate structures of the tympanic cavity from dust, foreign bodies, and the injurious influences of sudden changes in temperature.

5. Anatomical Peculiarities of the Eustachian Tube.

In addition to the fact, already stated, that the larger part of this channel is lined with ciliated columnar epithelium (the cilia of which move constantly in the direction of the pharynx), there are one or two others which are worthy of being mentioned.

In the first place, the total length of the channel, from the pharyngeal orifice to the tympanum, is about 36 mm. ($=1\frac{3}{8}$ inch). When the head is in the erect posture, the long axis of the tube is pointed in a forward, downward, and inward direction from the tympanum. Throughout one-third of its course from the latter cavity—*i.e.*, for a distance of about half an inch—the tube consists of a comparatively thin mucous membrane that rests against the inner surface of a cylinder of bone; while for the rest of the distance the walls are composed largely of cartilage. In a state of rest the opposite surfaces of the mucous membrane of this cartilaginous part of the tube lie in contact, in a vertical plane. In other words, in a cross-section the calibre of this part of the tube (when in this state of rest) would be represented by a vertical slit. The arrangement

of the cartilaginous walls is such, however, that when the fibres of the levator palati muscle which are attached to it contract, one of these vertically placed walls is pulled away from the other—or, in other words, this part of the Eustachian tube is then freely opened. It would seem, therefore, as if there were many brief periods throughout every twenty-four hours when air did not gain access to the tympanic cavity. On the other hand, the levator palati muscle is rarely in a state of rest. Glandular structures (mucous glands) are numerous throughout this cartilaginous part of the tube, the calibre of which increases rapidly from above downward. Jacobson gives the following data in relation to this point:—

Dimensions of the tube at the narrowest part = 1.5 mm. × 3 mm.
Dimensions of the tube at its pharyngeal mouth = 7 mm. × 13 mm.

6. Mode of Attachment of the Malleus to the Membrana Tympani and to the Neighboring Wall of Bone.

If we disconnect the incus from the malleus, thus leaving the latter ossicle free to follow the movements of the drum-

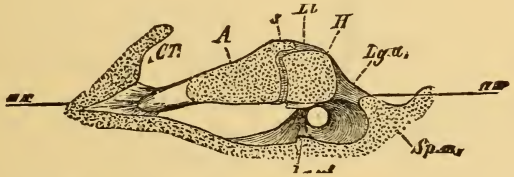

Fig. 37.—View of the Malleus and Incus as Seen from Above (diagrammatic). (After Hensen.) *A*, Incus; *H*, malleus; *Lg.a*, ligamentum anticum; *ax*, *ax*, axis-line.

membrane, and then press upon it from different directions and at different points, we find that its attachments are of such a nature that it can only rotate inward and outward, as far as the drum-membrane will permit it to rotate, around an axis corresponding to a line drawn from the

spina tympanica posterior through the neck of the malleus, and finally through the band of fibres known as the ligamentum anticum of the malleus (Fig. 37, *Lg.a*). This axis-line is represented in the accompanying figure by a straight line running from *ax* to *ax*.

7. Mode of Attachment of the Malleus to the Incus.

These two ossicles are attached to each other in a peculiar manner. As will be seen in Figs. 35 and 38, the head of the malleus and the body of the incus to a certain extent interlock. Helmholtz, who was the first to describe the real nature of the malleo-incudal joint, compared it to "the joint used in certain watch-keys, where the handle cannot be turned in one direction without carrying the steel shell with it, while in the opposite direction it meets with only slight resistance" (*Mechanik der Gehörknöchelchen*, Bonn, 1869). As a result of this peculiar union between the two ossicles, an excursion of the head of the malleus from within outward—corresponding to an excursion of the membrana tympani in the reverse direction—will, by reason of the fact that the short process of the incus is quite firmly anchored to the posterior wall of the tympanic cavity, cause the forward part of the body of this ossicle to be lifted both upward and outward. As a further result of this lifting of the body of the incus upward and outward, the end of the long lever which projects downward from the incus, and

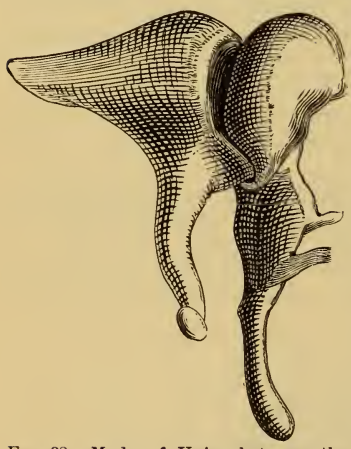

FIG. 38.—Mode of Union between the Head of the Malleus and the Body of the Incus. (After Helmholtz.)

which is known by the name of its long process, will be made to rotate upward and inward, and probably a little forward, through a short arc of a circle. The axis-line of the rotatory movements of the incus, it will thus be seen, is quite different from that of the malleus. With the reverse excursion of the latter ossicle, all direct pressure upon the incus is withdrawn, and this little bone returns to its former position of rest, partly through the force of gravity and partly through the elasticity of the articular capsule which binds it to the head of the malleus.

8. The Connections of the Stapes.

The third member of the chain of ossicles, or rather of the compound lever which we are endeavoring to describe, is the stapes. The head of this little bone articulates with the end of the long process of the incus. The opposing bony prominences are provided with regular articular surfaces, and the joint thus formed is enveloped by a capsular ligament and lubricated, apparently, by synovial fluid. The capsular ligament holds the opposing articular surfaces together so firmly that the head of the stapes must necessarily follow all the movements of the long process of the incus. These movements, as we have just seen, would cause the head of the stapes to be carried, first in an inward, upward, and slightly forward direction, and then in the reverse direction back to the starting-point. What effect this excursion of the head of the stapes will have upon the foot-plate of this ossicle, depends upon the anatomical relations of the latter to the oval window. It will suffice here to state that these relations are of such a nature that they favor only one kind of motion on the part of the foot-plate, *viz.*, that of a treadle, which, with every inward excursion of the tympanic membrane, causes a displacement inward of the vestibular fluid which bathes its inner surface.

9. Muscles Attached to the Ossicles.

In the human being the compound lever composed of the ossicles is provided with two relatively powerful muscles—the *tensor tympani* and the *stapedius*. These are the only muscles with which the deeper structures of the ear are provided.[1]

(*a*) The belly of the *tensor tympani muscle* rests upon a gutter-like shelf of bone on one side of the membranous part of the Eustachian tube. At the tympanic orifice of the tube the muscular substance merges into a slender cylindrical tendon which passes backward to a point on the inner wall of the tympanum, at a level a little higher than that of the oval window, where it traverses a pulley-like structure which changes the line of traction of the tendon from a direction that is chiefly antero-posterior to one that is chiefly transverse. Its final insertion is on the inner surface of the malleus, directly opposite the situation of the short process, and about midway between the extreme tip of the handle and the top of the head of this ossicle. When the muscle contracts, therefore, it puts all the ligamentous attachments of the malleus, together with the membrana tympani itself, upon the stretch. It probably also causes a somewhat closer interlocking of the opposing articular surfaces of the malleo-incudal joint.

(*b*) The *stapedius muscle* is concealed within the pyramidal mass of bone which lies immediately back of the oval window. The belly of the muscle and the facial nerve lie side by side in their respective channels in the bone. The tendon emerges from the apex of the pyramid and passes directly forward to the head of the stapes. The contraction of the stapedius muscle will therefore produce a threefold effect: it will tend to drive the posterior margin or lip

[1] The so-called *laxator tympani* muscle does not exist.

of the foot-plate farther into the vestibule; it will also tend to lift the anterior margin or lip farther out from the vestibule; and, finally, it will bring the head of the ossicle into closer contact with the end of the long process of the incus. Thus, through the combined action of both these muscles every part of the transmitting apparatus of the middle ear may be rendered tense, or, in other words, ready to vibrate in quick sympathy with whatever tones may reach it from the outer world.

10. The Normal Aërostatic Conditions in the Middle Ear.

When it is remembered that air, if confined in any part of the living body, will undergo complete and rapid absorption by the surrounding blood-vessels unless it be frequently renewed, the importance, to the middle ear, of such an aërial channel as the Eustachian tube will at once be apparent. Through this channel a new supply of air, thoroughly warmed and freed from nearly all its load of dust, is constantly finding its way into the middle ear. An absolutely perfect equilibrium between the atmospheric pressure upon the external surface of the membrana tympani and the counter-pressure upon its inner surface is, as I believe, not required. The ideal condition—judged from the standpoint of acoustics—is that in which the external atmospheric pressure upon the membrana tympani is always slightly predominant; for this would mean, for the transmitting apparatus of the middle ear, an absence of that relaxed condition of the parts which is not favorable to the accurate progression, through them, of vibratory shocks. In the case of the middle ear of the human being—thanks to the peculiar construction of the Eustachian tube, to which I have already referred in section 5—this ideal condition seems to exist. There is not a broad and open channel through which air may constantly pass freely in both directions, but one which is lightly closed a large part of the

time. When, through the action of disease, the tubal mucous membrane becomes so swollen that the air in the pharyngeal vault cannot force its way into the middle ear, the absorption of that which is already imprisoned in that cavity advances rapidly, and the inadequately resisted atmospheric pressure upon the outer surface of the tympanic membrane soon forces it inward to what I might call the extreme normal limit. By the time this point is reached the diminution in pressure upon the walls of the blood-vessels of the middle ear (or, in other words, the tendency to a vacuum which is then established) permits the watery elements of the blood to escape, and in this way, for the moment, the equilibrium is in some measure re-established.

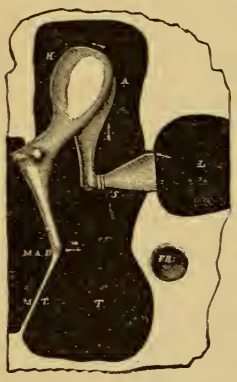

FIG. 39.—Diagrammatic Representation of the Transmitting Apparatus of the Middle Ear. *MAE*, Meatus auditorius externus; *MT*, membrana tympani; *M*, hammer or malleus; *A*, anvil or incus; *S*, stirrup or stapes; *L*, labyrinth; *FR*, fenestra rotunda. The arrows show the direction of movement in all parts of the apparatus during an inward excursion of the membrana tympani.

11. Mechanism of the Transmitting Apparatus of the Middle Ear as a Whole.

Very little remains to be said upon this subject except perhaps by way of recapitulation. Sonorous vibrations in the external auditory canal exert their influence first on the membrana tympani, causing it to perform rhythmical excursions inward and outward; the point of maximum breadth of these excursions being located at the centre of the membrane. These impulses are felt to an equal degree by the manubrium mallei, which virtually forms a part of this membrane. Then, owing to the fact that the malleus is attached in such a manner that it can only perform rotatory movements about

an axis which passes through it at a point midway between its upper and lower limits, the inward impulse of the tympanic membrane results in an outward excursion of the head of the ossicle; and, *vice versa*, an outward excursion of the membrane causes the head of the malleus to travel inward. Strictly speaking, the direction pursued by the latter is along an arc of a circle; and consequently, when a more careful investigation is made into the nature of the excursions performed by the lower end of the long process of the incus,—which ossicle, as it will be remembered, clings to the malleus as if it were part and parcel of its substance,—it will be found that the direction is chiefly upward, inward, and a little forward, in every inward excursion of the membrana tympani, and chiefly downward, outward, and a little backward in every outward excursion of this membrane. By reason of the fact that the stapes sits in the oval window in a position nearly at right angles to the long axis of the long process of the incus, and also partly by reason of the manner in which its foot-plate is attached to the margin of this window, the movements communicated by the incus to the head of that little ossicle cause its foot-plate to perform excursions closely resembling those of a treadle, every inward movement of which produces a displacement of the labyrinthine fluid.

CHAPTER VI.

CLASSIFICATION AND ETIOLOGY OF DISEASES OF THE MIDDLE EAR.

1. Classification.

The vast majority of the diseases of the middle ear which come under the physician's observation may most conveniently be placed under one or the other of the two great subdivisions—*Suppurative Inflammation of the Middle Ear* and *Non-Suppurative or Catarrhal Inflammation of the Middle Ear;* and those which cannot be placed in one of these two large subdivisions will be found to belong under some one of the following heads: *Syphilis*, *Tuberculosis*, *New-growths*, and *Traumatic Influences*. The classification of middle-ear inflammation as suppurative and non-suppurative or catarrhal is based entirely upon the fact that in the first of these a purulent exudation takes place in the tympanic cavity, while in the second the exudation consists of serum or mucus, or else there is no perceptible amount of exudation. In the first class the pus, as a rule, finds an outlet for itself through the tympanic membrane into the external auditory canal; but in exceptional cases the discharge may take place by way of the Eustachian tube, the tympanic membrane remaining intact.

In addition to this subdivision into two great classes, it is sometimes convenient to establish smaller groups of diseases of the middle ear. Thus, for example, there is very often a localization of the inflammation in some one part of the complex system of cavities which together constitute

the middle ear. The locality affected may be the Eustachian tube, or the vault of the tympanum, or the mastoid region; and the recognition of this fact furnishes a sufficient warrant for establishing a classification which is based upon these anatomical differences. Then again, the lesions produced by the disease may be taken as a basis for still another classification. Thus, for example, when the bone structure is invaded and a portion of it dies, we speak of the case as one of bone caries or necrosis; when the mucous membrane manifests a decided tendency to produce new connective tissue, we term the inflammation proliferative, or hypertrophic, or hyperplastic; and when this same mucous membrane, in its character of a periosteum, produces new bone tissue, we qualify the inflammation as an ossifying or hyperostotic otitis. Finally, the differences in the products of a middle-ear inflammation may furnish a convenient basis for establishing certain distinctive classes. Thus, for example, when this product consists mainly of serum, the term otitis media serosa is often employed; when blood forms a noticeable part of it, the expression otitis media hæmorrhagica is preferred; and, finally, when stringy mucus constitutes a prominent characteristic, we speak of the case as one of otitis media mucosa. All these different terms are used to a greater or less extent by writers on otological subjects, and they certainly serve a most convenient purpose.

2. General Etiology.

The causes of inflammations of the middle ear are recognized to-day as being more numerous than they were supposed to be a few years ago; and it is reasonably certain that in any given case several of these causes co-operate at the same time to bring the disease into activity; but we are as yet unable to assign to each of these different factors its proper share in the work. *Micro-organisms*, as I have

already stated, undoubtedly play a very important part in the etiology of middle-ear inflammations, but it is equally certain that unless the mucous membrane of this system of cavities, or of some contiguous region like the pharyngeal vault, be previously put into a vulnerable condition, these micro-organisms will be powerless for evil. An inflammation of the middle ear, for example, often results from "taking cold." This is the apparent cause in a very large percentage of all such inflammations. If we analyze what takes place in the nasal and pharyngeal mucous membrane when the heated and generally perspiring surface of the body is adequately chilled—which is the first step in the process of "taking cold"—we shall find that this membrane becomes the seat of a well-marked hyperæmia. The blood-vessels are greatly distended, and in consequence they become, for a certain length of time, paretic. This is doubtless the time when the micro-organisms which are known to be almost constantly present in the mucus of the pharyngeal vault are able to gain an entrance through the epithelial structures into the lymphatics and the blood-vessels of these parts. In other words, this mucous membrane, which in its ordinary state of health cannot be invaded by these pathogenic micro-organisms, now lacks the power successfully to resist such an invasion; in brief, it has now become vulnerable. The establishment of such a *vulnerability* in the naso-pharyngeal mucous membrane is, therefore, the first stage of the disease in a very large proportion of cases of middle-ear inflammation. The next and later stages follow very naturally upon the first one. The pathway leading to the middle ear is not always the route chosen by the advancing horde of pathogenic organisms, and so this particular region may escape. They are very likely, for example, to travel downward along the bronchial tubes. But in other instances—and these constitute a large percentage, though scarcely a majority, of all cases of "cold

in the head"—they advance along the Eustachian tube and give rise to some form of middle-ear inflammation. This advance, doubtless, is either subepithelial or intravascular, and not over the surface of the mucous membrane,—or at least not mainly along this route.

There are unquestionably other ways in which a condition of vulnerability may be established either in some part of the middle ear or in the pharyngeal vault; this latter being the more common starting-point of such middle-ear inflammations. Thus, for example, the exanthematous diseases may, in some way at present unknown to us, confer upon the tympanic mucous membrane a high degree of vulnerability to the attacks of at least some of the pathogenic micro-organisms (the streptococci, for example). The same is true, in perhaps a lesser degree, of such diseases as typhoid fever and the grippe (or epidemic influenza). Then, again, the diabetic condition robs the tissues of various parts of the body—and of this region among the rest—of their normal defensive powers against bacterial invasion. Finally, the entrance of salt water into the middle ear—either as a result of sea-bathing or from the employment of a solution of salt in a nasal douche—often prepares the way for an inflammation of this region which may prove to be of the most serious nature. Under these circumstances the salt alone can scarcely be held responsible for an inflammation of such severity. Its direct power for evil probably extends no further than to cause a marked degree of hyperæmia; but, then, on the other hand, this latter condition of vasomotor paresis is the very one which I have already mentioned as being, in all probability, one of the prerequisites for a successful bacterial invasion.

In addition to these more direct causes of inflammation of the middle ear, there are others which might be designated as collateral causes. While in most cases it is probably correct to speak of them as playing only an indirect

part, in a large minority they should be credited with the higher rôle of direct predisposing causes. I refer more particularly to the presence of *hypertrophied lymphoid tissue* in the vault of the pharynx. This pathological condition, as is well known, often keeps the blood-vessels of the middle ear for weeks or months at a time in a dilated condition, and in this manner predisposes this region to inflammatory attacks which are often of the most serious character.

When we come to consider the question of tuberculous disease of the middle ear, we find that another factor—one that plays in all the other forms of inflammation an insignificant, if not an altogether negative part—assumes here a good deal of prominence. I refer to the influence of *heredity*. There is no reasonable doubt at the present day that tubercle bacilli, when carried into the middle ear by the air which passes through the Eustachian tube, cannot effect a lodgment in this cavity, provided the mucous membrane which lines it be in a healthy condition. If this were not the case, tuberculous disease of the middle ear would certainly be much more common than it is. As a matter of fact, it is comparatively rare—at least as a primary disease. But when the mucous membrane of the tympanic cavity has, through inherited influences, lost its normal defensive powers against the various inimical micro-organisms ever present in the air, then a colony of tubercle bacilli may establish itself in some part of that cavity.

Up to the present time our knowledge of the precise part played by the other micro-organisms found in inflammations of the middle ear has not advanced very far. We know positively that the following varieties of micro-organisms are the principal etiological factors in all such inflammations: the streptococcus pyogenes, the staphylococcus pyogenes aureus, the staphylococcus pyogenes albus, the diplococcus pneumoniæ of Fraenkel and Weichselbaum, the pneumobacillus of Friedländer, and the bacillus pyocy-

aneus. The first four varieties are those which are the most often found in inflammations of the middle ear. It appears, from the examinations which have thus far been made, that the infecting agents may all belong to one species, or the invasion may be participated in by different micro-organisms. Finally, it may be said that the staphylococci generally cause localized inflammations, whereas the streptococci are responsible for phlegmonous and widely extending inflammations.

The character and course of an inflammation of the middle ear depend, in any given case, not only upon the nature of the pathogenic micro-organisms which have invaded the region, and upon the defensive powers possessed by the individual, but also in large measure upon the anatomical relations which happen to exist in that particular case. These relations, as is well known, differ widely in different individuals; one person having pneumatic spaces in large number and of large size, while another possesses very few such spaces, and these few of insignificant size. The same differences are observed in the extent to which the blood-vessels of the middle ear communicate with those of the different soft parts contained in the cranial cavity. It is apparent, therefore, that individuals differ widely in regard to their liability to experience a serious acute inflammation of the middle ear.

Finally, the condition known as *goutiness* or *lithæmia* must be recognized as an occasional etiological factor in the non-suppurative forms of inflammation of the middle ear. It rarely asserts its influence before adult life, and its manifestations are only too easily overlooked at any age.

CHAPTER VII.

NON-SUPPURATIVE OR CATARRHAL AFFECTIONS OF THE MIDDLE EAR.

The non-suppurative inflammations of the middle ear constitute a majority of all the ear diseases encountered in practice. The features which chiefly distinguish them from the purulent inflammations are the following: they run their course more quietly; they cause either no secretion whatever, or simply one that consists of serum or of mucus; micro-organisms play only an insignificant part or no part whatever in the process; and in nearly every case it is safe to assume that some nasal or pharyngeal vault lesion is the immediate active cause of the disease. The pathological alterations which are often present are: first, hyperæmia and œdematous swelling of the mucous membrane, sometimes limited to the Eustachian tube alone, at other times involving both the tubal and the tympanic mucous membrane; second, a certain amount of proliferation of the connective-tissue elements; and, third, after the preceding stages have lasted for months, or perhaps even for years, an atrophy and hardening (sclerosis) of the previously inflamed mucous membrane. As further results of these pathological changes the tympanic membrane will be found to occupy an abnormally depressed position, and, as time goes on, the ossicular joints are apt to lose their normal degree of mobility. Impaired hearing, subjective noises, and a stuffy or tight sensation in the affected ear, with occasionally a little vertigo or light-headedness, are the

usual symptoms belonging to a non-suppurative inflammation of the middle ear.

While there are no sharp dividing-lines between the different types of catarrhal inflammation of the middle ear, it is desirable, for the purposes of description, to treat them as distinct groups. Four such separate subdivisions may easily be established, *viz.*: 1. Eustachian Catarrh; 2. Acute Catarrhal Inflammation of the Middle Ear; 3. Serous or Mucous Exudation into the Tympanic Cavity (otitis media serosa sive mucosa); 4. Chronic Catarrhal Inflammation of the Middle Ear.

1. Simple Eustachian Catarrh.

The ordinary "cold in the head" rarely runs its course without involving at least one of the Eustachian tubes to a greater or less extent. The patient experiences a stuffy or

FIG. 40.—Normal Position of Drum-Membrane. (After Hartmann.)

FIG. 41.—Drum-Membrane drawn Inward Markedly. (After Hartmann.)

a tight sensation in the corresponding ear, perhaps also at the same time some tinnitus, and a certain degree of resonance of his or her own voice in that ear. The hearing is very little, if at all, affected. On inspection with the mirror and speculum it will be found that the membrana tympani is altered in only one or two respects. In the first place, it is depressed to a degree proportionate to the narrowing of the tube (see pp. 171, 172); and, in the second place, it may show a little hyperæmia along the manubrium mallei or in the neighborhood of Shrapnell's membrane.

When we find a higher degree of hyperæmia of these parts, we may be sure that the disease has invaded the tympanic cavity and is not confined to the Eustachian tube. If in a simple case of tubal catarrh the middle ear be cautiously inflated, the tympanic membrane will return not merely to its normal position, but to one which is appreciably nearer to the eye of the observer (see Fig. 42). It will present an outwardly convex appearance. If the narrowing of the tube be well marked, this hyperdistention (after inflation) will continue for a period of several minutes, or even for a longer time; while in the ordinary cases the very first act of swallowing which the patient may perform usually permits the excess of air encaged in the tympanic cavity to escape back into the vault of the pharynx.

Fig. 42.—Hyperdistention of the Drum-Membrane. (After Politzer.)

The *prognosis*, in all recent cases of Eustachian catarrh, is good. In fact, in most cases the disease is of short duration, and passes away without any treatment. But if *treatment* should seem to be required, a few applications of a vaso-motor stimulant—a ten- or a fifteen-grain silver-nitrate solution—to the vault of the pharynx will soon overcome the difficulty in all uncomplicated cases.

2. Acute Catarrhal Inflammation of the Middle Ear.

What I have described in the previous section as a Eustachian catarrh proves, in very many cases, to be simply the onset, the first stage, of an acute catarrhal inflammation of the middle ear. The hyperæmia extends beyond the strict domain of the tube, and involves, to a greater or less degree, the entire tympanic cavity. If it persists for a few hours or an entire day, the watery elements of the blood will

begin to escape from these distended vessels into the tissues of the mucous membrane and even out upon its free surface. When this latter effusion is sufficiently copious, enough intratympanic pressure may be developed to cause pain. The boundary line between such cases and those which eventually develop into the suppurative variety is not distinct; and this fact naturally suggests the thought that the two varieties may after all depend upon precisely the same etiological factors; the clinical differences being due to the fact that in the milder catarrhal attacks the micro-organisms are less numerous or less virulent than they are in the suppurative. However this may be, we cannot as yet dispense with our present method of dividing these cases into two distinct classes.

The cases of acute catarrhal inflammation of the middle ear vary markedly in severity. In the mildest ones there may be a few twinges of pain in the affected ear, but nothing more; and even in the most severe the pain does not last longer than a few hours, although it may return on several successive days. Very many of the "earaches" of young children, from two to ten years of age, are due to such an acute catarrhal inflammation. The pain is very apt to come on during the night or late in the afternoon, while during the earlier part of the day the child may be quite free from pain. In the milder forms the picture presented by the tympanic membrane differs very little from that which I have described as belonging to an attack of Eustachian catarrh; at most, the evidences of hyperæmia of the tympanic mucous membrane will be more pronounced than they are in that condition. On the other hand, the picture presented by the tympanic membrane, a few hours after the onset of a fairly severe attack, is often of a most striking character. It is a picture of obstructed venous circulation of a high degree. In less severe cases a well-marked hyperæmia—most pronounced in the vicinity

of Shrapnell's membrane, and shading off gradually from there in a downward direction—is all that we shall be able to see when we examine the region with the speculum and reflected light.

The *prognosis* is almost invariably good in this form of catarrhal inflammation of the middle ear. Generally, in the course of two or three weeks the inflammation entirely disappears, and the hearing returns to its previous normal condition.

So far as the *diagnosis* is concerned, an error is scarcely possible. The evidences of inflammation are too plainly marked for a careful observer to be easily misled in his interpretation of the conditions presented. The questions which suggest themselves to his mind are, first: Is this a simple catarrhal inflammation, or is it the beginning of a severe purulent inflammation? Mere inspection will not suffice for the settlement of this question: the subjective symptoms, and especially that of pain, must be weighed in connection with the condition of the drum-membrane. In children, the thermometer may aid us materially in arriving at a correct conclusion; in adults, it is of comparatively little value. The second question is, Is the red and swollen condition of the membrana tympani the expression of an inflammation which began originally in the middle ear, or is it due to an extension of a diffuse inflammation of the canal on to the drum-membrane? This is sometimes a difficult question to answer. If an inflammation of the middle ear has progressed so far as to involve the inner end of the external auditory canal, we may be quite sure of two things: there will be marked diminution of the hearing, and a history of rather severe pain. On the other hand, the insignificance of the pain and the slight impairment of the hearing are very striking features in those cases in which the inflammation of the auditory canal is the primary affection, and that of the drum-membrane merely a secondary

affair. In exceptional cases, marked pain and decided impairment of hearing may characterize the type of disease last mentioned. Under such circumstances it may not be possible to arrive at a correct diagnosis without further observation of the course which the disease pursues.

Finally, it must not be forgotten that in these cases, as in all others in which the middle ear is the seat of some pathological process, our task as diagnosticians is not completed until we shall have fully ascertained what is the state of the pharynx, vault, and nasal passages.

When we are sure of our diagnosis, the question of *treatment* becomes a very simple matter. Very little interference is necessary. The breaking down and removal of any clotted blood that may be encysted at the inner end of the meatus, the use of the simple hot douche or of poulticing when there is pain, paracentesis of the membrana tympani if it be found to be unduly tense, the reduction of the hyperæmia of the pharyngeal vault by the employment of a mop saturated with a suitable silver-nitrate solution, and the occasional employment of Politzer's method of inflating the middle ears *after the pain has entirely disappeared*— these are the therapeutic measures which will generally be found useful in the management of this class of cases.

3. Serous or Mucous Exudation into the Middle Ear.

The form of middle-ear disease which I have just described in the previous section is often associated with an exudation of fluid into the tympanic cavity; but it is not to this kind of accumulation of fluid in the middle ear that the terms enumerated in the title of the present section have reference. The condition which I am about to describe is one in which a comparatively normal tympanic cavity is found to contain a variable amount of either serum or mucus, or of a fluid which represents a combination of the two. Such a state of affairs usually indicates a persistence

of those pathological conditions of the vault of the pharynx which favor a narrowing of the tubal outlet. While the first outpouring of fluid into the tympanic cavity undoubtedly represented an *hydrops e vacuo*, the failure of this fluid to undergo absorption, even after the surrounding walls have apparently been restored to a normal state, shows two things: first, that the drainage of the tympanic cavity by way of the Eustachian tube is still obstructed; and, second, that the processes of absorption are not acting normally. The admixture of mucus may be looked for in those cases in which there is not simply an interference with the drainage of the Eustachian tube, but also a persistence of the phenomenon of hyperæmia, which causes the mucous glands of the tube to secrete more actively than usual.

The *symptomatology* of these cases is essentially the same as that of the ordinary cases of non-suppurative inflammation. There are certain symptoms, however, which of themselves are almost sufficient to warrant a diagnosis of fluid exudation into the middle ear. One of these is the sudden change from somewhat poor to good hearing, or the reverse. This change is not like that which so often occurs in cases of impacted cerumen, where the brief return of the hearing is accompanied by an explosive sound, due to the sudden restoration of a communication between the body of air lying between the drum-membrane and the ceruminous mass, and that which lies outside the latter; the hearing either simply becomes clouded, or, in an equally quiet manner, the cloud seems to disappear. These changes in the hearing are clearly due to changes in the position occupied by the fluid. In a few cases the patient is able to state definitely in what positions of the head the hearing seems to be normal. These are most commonly the position with the head thrown far backward (fluid escapes into the antrum), and that with the head bent far forward. In both of these positions the fluid, if not too viscid and if not

too copious, will, in obedience to the law of gravity, flow away from the oval and round windows, thus leaving the ossicles and the membrana tympani secundaria free to perform their functions properly.

Another symptom which is peculiar to these cases is the sensation of something moving in the ear. This, as a matter of course, is not felt when the head is quiet, but simply when the head is moved rather suddenly. Sometimes the patient gives a correct diagnosis of his condition in the very first words of his complaint: "I went in bathing, and got some water into my ear; and I am unable to get it out." He imagines that the water found its way into the ear by way of the external auditory canal; whereas the chilling of the surface of the body, or the accidental entrance of water into the middle ear by way of the Eustachian tube, has caused an exudation of fluid to take place in the tympanum in one of the ways already described. Finally, subjective crackling, squeaking, and bubbling sounds may be due to the presence of free fluid in the middle ear; they are just as likely, however, to owe their origin to an abnormally moist condition of the Eustachian tube. Of more decided value is the symptom of hearing gurgling sounds in the ear during the acts of coughing, sneezing, and swallowing.

The *course of the disease* is a very variable one, although in the majority of instances the fluid exudation is soon absorbed and the ear returns to a normal condition.

Diagnosis.—The appearances presented by the tympanic membrane when a collection of serum, muco-serum, or mucus, lies behind it, vary greatly. The simplest picture is that which is seen when the fluid contained in the tympanic cavity is comparatively small in quantity and consists of a thin serum. The upper level of this mass of fluid can then be seen like a hair crossing the tympanic membrane in a more or less horizontal direction, as shown

in Fig. 43. When the patient moves his head backward or forward, this slightly curved or undulating line will be

FIG. 43.—Collection of Serous Exudate in the Lower Part of Right Tympanum. The glistening curved line which crosses the picture represents the upper level of the fluid. (After Politzer.)

FIG. 44.—The Same Condition, as seen in Another Patient. In this case the line of the upper limit of the fluid is wavy. (After Politzer.)

observed to maintain constantly its horizontal position. (Compare the two pictures, Figs. 44 and 45.) When the fluid contained in the tympanum rises to a level higher than the upper limit of the membrana tympani, our diagnosis will have to be made with the aid of other data; for there will be no "fluid line" in the picture to indicate that serum is imprisoned in the middle ear. When this is the situation of affairs, the history of the case may afford us some assistance in ascertaining the truth. Or, if experience has taught us to observe closely the differences in the apparent coloring of the tympanic membrane, our suspicions may be aroused by the peculiar greenish or purple or slaty color which it presents. These different shades of color may be explained in the following manner: The light thrown into

FIG. 45.—Appearance of the Drum-Membrane (same case as that shown in Fig. 44) when the patient's head is thrown far backward. The line of the fluid now runs nearly parallel with the handle of the hammer, instead of at right angles with it. (After Politzer.)

the external auditory canal by the concave mirror first passes through the membrana tympani, and then through the mass of serous fluid, before it strikes upon the somewhat congested mucous membrane covering the inner wall of the tympanum. The color of such a congested mucous membrane is not always the same. It may be a shade of red which is only a little more pronounced than the natural pinkish hue of the membrane; or it may be a decided purple, as when there is some interference with the venous circulation of the part. But the rays of light which are reflected back from this red or purple surface to the eye of the observer must first pass through the intervening mass of yellowish serum and then through the tympanic membrane; and there can be little doubt that the influence of this yellow medium is competent to convert the red into a dull green, and the purple or blue into a slaty hue. Unfortunately, however, the diagnostic value of these departures from the normal coloring of the membrana tympani cannot always be depended upon. The deep greenish or slaty color may come, not from a mass of serum lying free in the tympanic cavity, but from some which is entangled in the meshes of the tympanic mucous membrane; for the passage of the reflected rays through even this comparatively thin medium of yellow seems to be sufficient to transform their original red or purple into these same darker shades of green or gray. But if the peculiar color be really due to the presence of free serum in the tympanum, the inflation of that cavity will make the presence of this fluid known by the appearance of bubbles of air (see Fig. 46) or of the "fluid line" where before nothing could be seen but a uniform, unbroken surface. Auscultation during the act of inflation may also aid us in arriving at a correct conclusion. In cases of an accumulation of mucus, it is perhaps the exception for râles to be heard; in fact, the air, forced into the Eustachian tube by inflation, does not seem to

reach the cavity of the tympanum at all. In the second place, the appearance of the drum-membrane in cases of otitis media mucosa is usually quite different from that observed in well-marked cases of otitis media serosa. It often has a peculiar dead, milky, opaque appearance, which, unfortunately, is sometimes also observed in cases of the serous variety. Hence, without paracentesis of the membrane, we can scarcely do more than entertain a strong suspicion that the case is one of an accumulation of mucus in the tympanic cavity. After paracentesis has been performed, and the exuded material has been forced through the perforation into the auditory canal, it becomes, of course, an easy matter to make an absolute diagnosis.

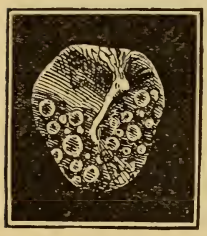

FIG. 46.—Foamy Secretion in the Tympanum after Inflation in a Case of Serous Accumulation. From a patient with acute naso-pharyngeal catarrh. (After Politzer.)

Treatment.—The mere fact that a certain amount of free exudation is lodged in the tympanic cavity does not necessitate any material alteration of the treatment which is required in ordinary cases of catarrhal inflammation of the middle ear. The mere evacuation of this fluid through an opening made with the knife in the tympanic membrane may afford relief for a short time; but usually the exudation accumulates a second time and a new opening has to be made in the membrane. The more rational procedure is to treat the pathological conditions (nasal or pharyngeal) of which this exudation is merely a symptom, and not to resort to paracentesis.

4. Chronic Catarrhal Inflammation of the Middle Ear.

The expression "acute catarrhal inflammation of the middle ear" is rightly employed when it is applied to a case in which the underlying cause is of a transitory nature—as,

for example, a "cold in the head," a mild attack of influenza, perhaps also an attack of hay fever, and still other causes which do not, at the present moment, occur to my mind. It is also rightly employed when it is applied to the early stages of those cases in which a latent goutiness or certain nasal or vault lesions of a fixed character are the cause of the middle-ear inflammation. But when these etiological factors of a more permanent character are not removed by treatment, and as a result the middle ear continues for an indefinite period to be the seat of all sorts of vascular, nutritional, and aërostatic disturbances, the combination of these various pathological phenomena very properly receives the name of "chronic catarrhal inflammation of the middle ear" (otitis media catarrhalis chronica).

Etiology.—The most important factors in the causation of a chronic catarrhal inflammation of the midde ear are unquestionably the various pathological processes and lesions which are located in the upper pharynx, the nasopharyngeal vault, and the nasal passages. The chief of these are the following: hypertrophy of the lymphoid tissue which is located in the vault of the pharynx (Luschka's tonsil), hypertrophy of the faucial tonsils, deviations of the septum narium, hypertrophy of both the middle and lower turbinated bodies, and hyperostosis or hyperchondrosis of the nasal septum. There are four ways in which they may perpetuate a chronic catarrhal inflammation of the middle ear, *viz.*, first, by a direct mechanical interference with the ventilation and drainage of the Eustachian tube; second, by the direct extension of the proliferative inflammation which is going on in the mucous membrane of the vault; third, by the frequent establishment of a partial vacuum in the Eustachian tubes; and, fourth, by the indirect provocation of such a middle-ear inflammation through reflex influences.

(*a*) The lesions which may interfere with the free access

of air to the middle ear by way of the Eustachian tube are: unusually voluminous hypertrophied lymphoid tissue, a polypoid hypertrophy of the posterior extremity of the middle turbinated body, and a greatly enlarged faucial tonsil. If it be remembered, however, that there is a great distance between the mouth of the Eustachian tube and the

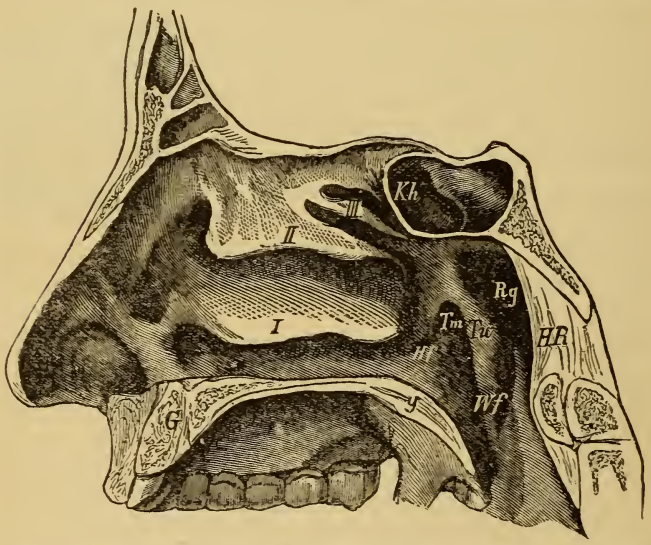

Fig. 47.—Anatomical Relations of the Nasal Passages and Pharynx to the Eustachian Tube. I, II, III, Lower, middle, and upper turbinated bones; *HR*, posterior wall of pharynx; *Rg*, Rosenmüller's fossa; *Tw*, prominence separating the tubal orifice from Rosenmüller's fossa; *Tm*, orifice of Eustachian tube; *G*, hard palate; *g*, velum palati; *Kh*, cavity of sphenoid bone. (After Hartmann.)

upper edge of the faucial tonsil when in a normal condition (see Fig. 47), it will be appreciated at once how enormously the latter must increase in size in an upward direction before it can actually obstruct the tubal orifice. On the other hand, the hypertrophied glandular tissues are apt to be surrounded by a good deal of ropy mucus, and it is not unlikely

that the obstruction observed in these cases is due in some measure to this product.

(*b*) The close anatomical relationship which exists between these two regions makes it almost impossible that an inflammation, or at least a process of hyperplasia, should go on for any length of time in the larger area of the vault without involving the smaller one of the Eustachian tube and tympanic cavity; and there can be no reasonable doubt that this is precisely what does take place in a large proportion of all the cases that belong in this category. As instances of a similar extension of catarrhal inflammation from a larger to a smaller related area, I might mention the catarrhal involvement of the gall and tear ducts.

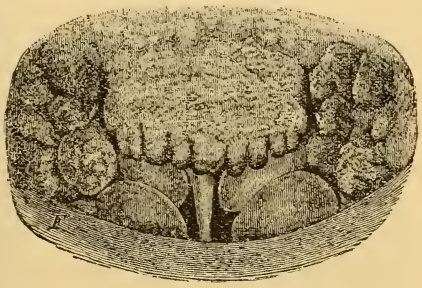

FIG. 48.—Adenoid Vegetations at the Vault of the Pharynx. The orifices of the Eustachian tubes are completely concealed by the growths. Copied from nature by means of the rhinoscopic mirror. (After Meyer.)

(*c*) In individuals who have nasal passages of a normal calibre the act of swallowing is not associated with any appreciable disturbance of the aërostatic conditions in the vault of the pharynx or in the Eustachian tubes; for at the instant when the swallowing begins to create a vacuum in the vault, air rushes in through the nasal passages and makes good the deficiency. If anybody, however, wishes to appreciate how effective the act of swallowing is, as a means of exhausting the air in the vault, he has only to close his own nasal passages and then to perform the act of swallowing. By so doing he will be painfully reminded that the act in question—in the presence of closed nasal passages—produces almost as perfect a vacuum in the vault

as would a successfully applied dry cup. Between this extreme and the normal aërostatic conditions of the vault, it is possible, during the act of swallowing, to obtain all possible degrees of a vacuum in that cavity. The various degrees of swelling of the turbinated bodies, deflections of the nasal septum, and spurs of bone or cartilage projecting from the side of this septum, are all capable of narrowing to a greater or less extent the nasal passages, and, consequently, of producing, with every act of swallowing, corresponding degrees of a vacuum in the vault. Hyperæmia of the naso-pharyngeal mucous membrane is the immediate result of the establishment of such a partial vacuum, and the degree of this hyperæmia will be directly proportionate to the amount of narrowing which the spur of bone, or the bending of the septum, or the hypertrophied turbinated body, has caused in the nasal passages. In the higher degrees of nasal stenosis even the simple act of breathing (with the mouth closed) is competent to create a partial vacuum in the vault. Swallowing is an act of such frequent recurrence that one can easily understand how, in these cases of nasal stenosis, the hyperæmia of the vault—and necessarily also of the Eustachian tubes—must gradually become a more or less constant feature.

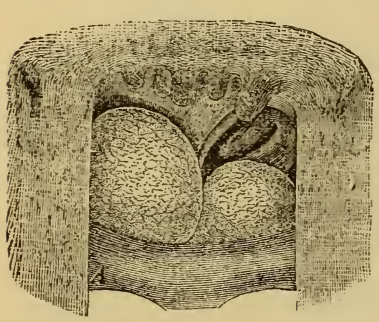

Fig. 49.—Another Case of Adenoid Vegetations Springing from the Upper Wall of the Vault. The large, smooth, rounded masses represent jelly-like hypertrophies of the mucous membrane of both lower turbinated bodies. The larger of the two completely fills the posterior end of the corresponding nasal passage. (After Meyer.)

(*d*) It has been observed that a spur of bone, growing out from the nasal septum and impinging upon the opposite

and generally swollen turbinated body (either the middle or the lower one), is very apt to be associated with well-marked catarrhal disturbances in the corresponding middle ear; and, furthermore, that these disturbances are greater than would naturally be expected to result from the same degree of narrowing of the nasal passage *without* the added feature of pressure upon the mucous membrane. The conclusion is naturally drawn that it is the irritation caused by

FIG. 50.

FIG. 51.

FIGS. 50 and 51.—Photographs of a Lad of about Fifteen Years of Age, from whose pharyngeal vault a mass of hypertrophied adenoid tissue was removed. Fig. 50 shows the facial expression which usually accompanies the higher degrees of this pathological condition, while Fig. 51 shows how completely this expression has been altered by the operative removal of the growths. (After Meyer.)

this pressure which, through reflected nerve action, produces the higher degree of disturbance in the middle ear. And the correctness of this hypothesis is strengthened by the fact that the removal of the spur and the reduction of the swelling of the turbinated body often effect a marked improvement in the condition of the ear.

In infants and young children hypertrophy of Luschka's and the faucial tonsils is practically the only local etiological factor with which the aural surgeon has to contend.

The strictly nasal lesions, on the other hand, predominate very decidedly in adult life. Associated with these, however, are sometimes found enlarged faucial tonsils and occasionally a remnant of a formerly enlarged Luschka's tonsil. In rare cases there will also be found some pathological condition of the ethmoid or frontal cells or of Highmore's antrum; and our attention will then have to be devoted to the cure of these, as being the primary sources of the entire chain of pathological phenomena.

In a few cases the general condition known as goutiness plays a more or less active part in the production of a chronic catarrhal inflammation of the middle ear, or in the aggravation of one which had primarily been called into existence by some vault or nasal disease.

Finally, there are various collateral factors which exert an appreciable—sometimes even a very marked—influence upon the course of the disease which we are now considering. Such are, for example: an occupation which subjects the patient's ears to frequent and somewhat violent concussions of the air; certain climatic conditions; and excessive tobacco-smoking.

Diagnosis.—The question here relates chiefly to the discovery of the causes which are slowly diminishing the hearing power and perhaps at the same time producing a distressing tinnitus. The problem is often a difficult one to solve, even for the skilled specialist of wide experience. To the beginner I would say: Study the appearance of the tympanic membrane carefully, in order to determine to what extent the disease is still of an active character. Then scrutinize carefully the nasal passages and the vault of the pharynx, in order that an accurate knowledge of the condition of these parts may be obtained. Finally, ascertain, by questioning the patient, to what extent the condition of goutiness—of sluggish metabolic changes—is playing a part in the case. The changes in the tympanic mem-

brane wrought by earlier stages of the disease or by other forms of disease will be discussed in a later chapter. The fact that the disease is still active will be evidenced by the presence of hyperæmia and infiltration of the tissues of the membrana tympani. So far as the nasal and vault lesions are concerned, these are to be learned in part by direct or reflected illumination of the regions, and in part by digital exploration of the vault of the pharynx.

Digital Exploration of the Pharyngeal Vault.—As regards the proper method of conducting this operation I will quote here from the description given by Dr. Robert Lewis, Jr., in my larger treatise:

"Before making a digital examination the toilette of the index finger should be carefully attended to, and the examination should be conducted as expeditiously as possible, for the operation is a very unpleasant procedure, which the patient generally resists, unless he or she possesses an unusual degree of self-control. The examination should be conducted as follows: The surgeon, standing on the right of his patient, should pass his left arm across the back of the patient's neck, to aid in steadying the uplifted head and to prevent as much as possible the struggle which is almost sure to occur in children. Then, with a couple of fingers of the left hand, press gently the patient's left cheek in between the jaws of the widely opened mouth; the object of this being to save the examiner's fingers from being bitten, as the patient would be compelled—if he attempted to close his jaws—to first bite his own cheek. As a third step the index finger of the examiner's right hand is to be rapidly introduced into the patient's mouth and up behind the uvula. After it has gained an entrance, the finger should be rapidly swept over the vault, and during this period of a few seconds the surgeon should have no difficulty in ascertaining the amount, consistency, and position of whatever hypertrophied tissue may be present. It

is possible, in certain cases, to see the enlarged Luschka's tonsil through the nares.

"There are three pathological conditions which it is possible to mistake for hypertrophy of the pharyngeal tonsil, *viz.*, a retro-pharyngeal abscess, a mucous or fibroid polypus, and a syphilitic gumma. In a retro-pharyngeal abscess the surface would be smooth and symmetrical, and fluctuation would be felt. There would also doubtless be pain and fever, probably with dyspnœa and choking. Furthermore, there would be a rapid onset of the symptoms, and the tumor would be located well down on the posterior wall of the pharynx. Nasal mucous polypi will be found to spring from the nasal cavity, and not from the walls of the vault; and fibroid tumors are very firm, with a smooth surface, and they do not yield under the pressure of the finger as adenoid growths always do. Specific gummata are smooth and hard before they break down, and afterward they are indurated and friable, and besides are very rarely found in this region."

Anterior and Posterior Rhinoscopic Examinations.—Here again I shall quote from Dr. Lewis's description of the way in which these examinations should be made:

"Having at our command the means of making anterior and posterior rhinoscopic examinations, we proceed to do so in the following manner: The patient should be seated in front of, and if possible on a level with, the surgeon; his head should be tilted a trifle backward and his mouth should be wide open; then the light should be thrown into the buccal cavity, and he should be ordered to breathe in slowly and as naturally as the circumstances will permit. Insert the tongue-depressor and pass it gently along the dorsum of the tongue until a sufficient surface is covered to hold the organ firmly in position. If this be done slowly and gently an otherwise sensitive patient may remain passive without retching throughout the examination. The

rhinoscopic mirror requires to be heated (to prevent cloudiness of its surface) before it is introduced into the faucial cavity; and, in order to make sure that it is not too hot, the surgeon should adopt the inflexible rule of testing the instrument upon his cheek or the back of his hand. Otherwise he may severely burn his patient, and so give rise to a very serious inflammation of some part of the fauces. When the mirror has been satisfactorily heated it should be introduced behind the uvula, in such a manner—if possible—as not to touch the parts. If this be accomplished without causing the patient to retch, it is likely that the examination will then be rapidly made. The mirror is to be moved in a rotatory manner, so as to gradually bring all the various anatomical or pathological parts, as the case may be, into view.

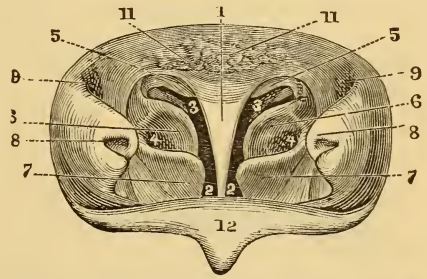

FIG. 52.—Rhinoscopic Image (from Cohen's "Diseases of the Throat"). 1, Vomer or nasal septum; 2, free space of nasal passages; 3, superior meatus; 4, middle meatus; 5, superior turbinated body; 6, middle turbinated body; 7, inferior turbinated body; 8, pharyngeal orifice of the Eustachian tube; 9, fossa of Rosenmüller; 11, glandular tissue; 12, posterior surface of uvula.

An endeavor should be made to first bring the vomer (Fig. 52) into the field of vision, as by the aid of this the other landmarks can be located. Then, in succession, the turbinated bodies, the vault of the pharynx, the fossa of Rosenmüller, the mouths of the Eustachian tubes, and the posterior surface of the uvula should all be examined. If the patient is unable to control the uvula and faucial muscles, the experiment may be tried of having him breathe through the nose or utter a nasal sound. By this expedient the muscles may often be brought under

control. If the experiment fails, a four-per-cent. solution of cocaine may be sprayed over the fauces, or the patient may be given a small piece of ice to suck; both of these measures tending to render the parts less irritable. But even after all these different measures have been tried, much patience and perseverance may be required before a satisfactory examination can be obtained. Thus, for example, it may be found necessary to ask the patient to practise regularly at home with a spoon, introduced into the mouth as a tongue-depressor. He should stand in front of a mirror while doing this, and should watch the movements of the uvula. Then, when he finds that he can do this without causing retching, he should practise with a cotton-tipped applicator until he can make an application to the pharynx without provoking retching. There are some patients, however, in whom all these means fail, and then our only available way of learning what is the condition of their pharyngeal vault is to resort to palpation.

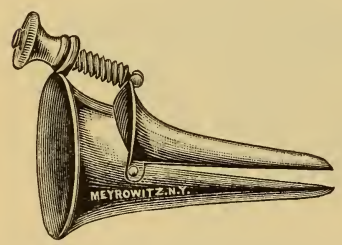

Fig. 53.—Duplay's Bi-valve Speculum.

"To make an anterior rhinoscopic examination is a task much less difficult than the one just described. The following are the various steps required: The light should be thrown into the patient's nostril, after lifting up the tip of the nose to a slight extent. The speculum (Fig. 53) should then be inserted and opened by means of the screw and nut. If there are any short hairs which obstruct the view, twist the speculum round an entire circle and this will flatten them down out of the way. Then carefully observe the color, shape, and condition of the turbinated bodies, as well as of the septum. If the turbinated bodies are swollen,

take a probe and ascertain to what extent the mucous membrane is movable upon the framework of bone. Also look for ridges or spurs or deviations of the septum, and if they exist, note their situation, their size, and the probable thickness of the septum at the site where they are located. If any discharge exists, determine its probable source and note its character, amount, and odor. When satisfied with the view obtained in this manner, spray the nasal cavities with a solution of cocaine, and, after the lapse of about five minutes, again repeat the examination. Note any change which may have taken place in the tissues—as, for example, a change from a previously red and swollen condition to one in which the parts are pale and reduced in size. The probe should also be used a second time, in order that further information may be gained in regard to the condition of the mucous membrane covering the turbinated bodies. In this way, for example, it is possible to determine whether an apparent enlargement of the parts is due to mere vascular dilatation or to a true hypertrophy. Furthermore, after the spraying with a cocaine solution, it will be possible, in most cases, to obtain a better view of the posterior nares, as well as of the pharynx, than before.

"Fig. 47 gives a fair idea of the size of the turbinated bodies and of their relations one to the other and to the neighboring parts of the nasal pharynx."

Pathology.—If we analyze the pathological phenomena which occur in the middle ear in cases of chronic catarrhal inflammation, we shall find that they may readily be subdivided into three groups, which correspond more or less closely with the three stages through which every chronic inflammation of a mucous membrane passes. The chief characteristics of these three groups are: 1, hyperæmia, or abnormal fulness of the blood-vessels; 2, hyperplasia of the connective-tissue elements; and 3, sclerosis and atrophy of the previously hypertrophied tissues. In most instances

a period of several years must elapse before the affected ear, in the natural progress of the disease, reaches the last of these three stages, but no definite period of time can be allotted to any one of them. Furthermore, in many cases, there are particular circumstances which hinder or favor an advance of the disease, and by reason of these the duration of one or both of the first two stages may be materially lengthened or shortened, as the case may be. My impression is, that the third stage, when once initiated, pursues a direct and more or less regular course, which cannot be influenced by treatment or any extraneous circumstances. It is the expression of a law which governs newly created connective tissue, and therefore must advance in strict obedience to that law. But, in so far as we may prevent or diminish the new-formation of connective tissue, to precisely the same degree does it lie in our power to prevent or diminish the effects of the sclerosis and atrophy which characterize the third stage.

Prognosis.—During the past ten years the prognosis, in cases of chronic catarrhal inflammation of the middle ear, has been steadily growing more favorable. The reasons for this are not far to seek. In former times we—by which I mean aural surgeons in general—did not appreciate, as we have since learned to do, the great importance of nasal and vault lesions in originating, as well as in perpetuating, chronic affections of the middle ear. Then, besides, it required a period of several years before we had learned fully how far it was safe to go in our interference surgically with these unfamiliar parts, and what were the best methods of solving the therapeutic problems which were here presented to us. In large measure these various difficulties have now been overcome, and as a result we are able at the present time to report as materially benefited, many cases which in the earlier period would have been dismissed as incurable. It is only in those which have distinctly reached the

stage of progressing or completed sclerosis that we are warranted in withholding all encouragement. There is also another aspect of the question which must not be overlooked. If it be admitted that these nasal and vault lesions are the chief causes of a chronic catarrhal inflammation of the middle ear, it must also be conceded that in removing these lesions, especially in the earlier years of life, we are performing a valuable piece of prophylactic work; that is, we are warding off a worse degree of deafness than that which may happen to be the patient's lot at that particular time.

Treatment.—The great majority of cases of chronic catarrhal inflammation of the middle ear owe their origin chiefly to some one or more of the nasal or vault lesions already mentioned. Consequently the rectification of these lesions constitutes the larger and the more important part of the treatment. How this shall be accomplished, in the case of each of these different lesions, is a matter of detail with which the present work cannot properly deal. Those who desire to obtain information in regard to these questions, must seek for it in the larger treatises.

For our present purposes, then, it may be assumed that the nasal cavities, the vault of the pharynx, and the fauces have received all the local surgical treatment which their respective pathological conditions demand. The question then arises, whether any further local measures, directed to the vault, Eustachian tube, and tympanic cavity, may or may not advantageously be undertaken. I will recapitulate briefly the different pathological conditions which are likely still to be present after the more conspicuous vault and nasal lesions have been remedied. They are as follows: more or less hyperæmia of the vault of the pharynx, the Eustachian tube, and the tympanic cavity; possibly a little free secretion in the latter cavity; more or less rigidity of the different ossicular joints or connections; abnormal dislocation inward of the tympanic membrane and connecting ossicula;

and perhaps also a somewhat dilated condition of the labyrinthine blood-vessels. We cannot say positively, in any given case, whether it be or be not practicable to diminish some or all of these abnormal conditions. In a general way, however, it may be said that when these alterations have existed for a long time, and particularly if the process of sclerosis has already set in, our efforts to improve them will almost surely be in vain. But in a fair number of cases the pathological alterations consist, to a greater or less extent, of lesions which are amenable to treatment: such, for example, as a paretic condition of the blood-vessels, and an infiltration of the connective tissue of the part with a serous fluid. Our methods of examination do not always furnish us with accurate information in regard to these conditions, and so we are occasionally obliged to undertake treatment tentatively—*i.e.*, without a positive knowledge that the lesions which impair the hearing are, to a certain extent, amenable to treatment.

The collateral measures which may sometimes be used to advantage in the cases which we have just been considering are the following: (*a*) inflations of the middle ear; (*b*) continuance of the silver applications to the vault of the pharynx; and (*c*) the adoption of certain general measures which have for their object an acceleration of the metabolic changes—an improvement in the processes of assimilation and retrograde metamorphosis of waste materials.

(*a*) *Inflations.*—The tendency of these is to diminish—probably through pressure—the hyperæmia and infiltration of the tubal and tympanic mucous membrane, and at the same time to gradually give greater mobility to the ossicular mechanism. I possess no facts which would warrant me in stating for just how long a period this part of the treatment should be kept up before we can safely determine that it is useless to persevere any longer. I must confess frankly that on this point my former teaching has perhaps erred

somewhat on the side of abandoning them too early. While it is still true that in most instances nothing is to be gained by pushing the experiment beyond the third week, there are undoubtedly a few cases in which the improvement does not begin to show itself until during the fourth or fifth week. Then, on the other hand, there must always be a certain amount of doubt, in the mind of a candid observer, as to how much of this improvement which begins at such an abnormally late date ought rightfully to be attributed to the inflations, and how much to the other therapeutic measures which may have been adopted. In any event, it is better to continue the former for an additional week or two needlessly (as may prove to be the case) than to abandon them prematurely.

(*b*) *Silver-Nitrate Applications to the Vault of the Pharynx.*—So long as any recognizable degree of hyperæmia continues to be present in this region it is advisable not to abandon the silver applications. Their beneficial influence, as I have stated elsewhere in this work, is not confined to the area of mucous membrane upon which the drug is applied, but extends—doubtless through reflex influences—to the congested tympanic cavity.

(*c*) *General Measures.*—Limited areas of hyperæmia may be influenced beneficially by all those various general measures which have for their object the acceleration of the metabolic changes in all parts of the body. In this category belong active outdoor exercise (horseback-riding, mountain-climbing, bicycle-riding, rowing, etc.), massage, the use of the Russian bath and even of ordinary hot baths, dieting, and the drinking of the Carlsbad Sprudel and other similar waters. In some instances greater benefit may be obtained from the administration of such remedies as iron, strychnine, and cod-liver oil, and from a residence in a dry climate, especially if the locality chosen is situated at a fairly high altitude (4,000–5,000 feet).

CHAPTER VIII.

ACUTE SUPPURATIVE INFLAMMATION OF THE MIDDLE EAR.

1. Definition.

A suppurative inflammation of the middle ear is one in which, at a comparatively early stage of the disease, the free exudation assumes a purulent character. At the onset of the attack the mucous membrane of the Eustachian tube and tympanic cavity becomes first hyperæmic and afterward œdematous. Then a serous or a sanguineo-serous fluid is poured out into the tympanum; and, finally, this assumes all the outward characteristics of pus. In a few exceptional cases this purulent fluid will find a sufficient outlet for itself along the channel of the Eustachian tube; but in the great majority of instances the latter passageway becomes closed almost at the very beginning of the attack, and then the exudation, under an ever-increasing pressure, forces an outlet for itself directly through the tissues of the membrana tympani. The subsequent history of the disease—both when the outlet is formed in this spontaneous manner and when it is established artificially by the surgeon's knife—is determined by a variety of circumstances, some of which are fixed (individual anatomical peculiarities) while others are of a purely accidental character (the special variety of micro-organism which has given rise to the suppurative inflammation; the patient's general condition of health at the time; the favorable or unfavorable character of his surroundings, etc.).

2. Influence of Individual Anatomical Peculiarities upon the Course of the Disease.

When nature, in any given case, provides easy pathways along which the inflammation (that is, the pyogenic micro-organisms) can travel from the tympanic cavity to various remote parts of the temporal bone, we shall not be surprised if the very first attack of acute middle-ear disease which that individual experiences should prove to be a particularly serious one. The following anatomical conditions may be considered as furnishing the easy pathways to which I have referred: free communication between the tympanum and the antrum, as well as between the latter and the surrounding system of air-containing cells; unusually large and unusually numerous pneumatic cells; unusually numerous anastomoses between the blood-vessels of the vault of the tympanum and those of the cranial cavity; and perhaps even the absence, over a small area, of the lamina of bone which separates the dura mater from the tympanic mucous membrane. All these are anatomical conditions which render it easy for the pathological germs to reach outlying regions, and to establish new and perhaps more serious foci of inflammatory action.

3. Influence of Other Factors.

I have already stated, on a previous page (chapter VI., section 2), how important is the part played by pathogenic micro-organisms in acute suppurative inflammations of the middle ear. I may now add that it is a fairly well-established fact that these organisms possess their maximum power of doing harm when the tissues which they invade are under an abnormal degree of pressure—one which must necessarily retard, if it does not arrest, the circulation of blood through the part. This circumstance suggests the idea

that an active circulation of blood affords great protection to tissues which have been invaded by these micro-organisms. It also explains the success which often follows paracentesis of the membrana tympani—an operation which, if properly performed, puts an end to the increased intratympanic pressure, and so permits the blood to again circulate freely. But if the entrance to the antrum happens at this time to be blocked—or if the entrances from the antrum into individual mastoid cells happen to be blocked—the paracentesis of the tympanic membrane will not put an end to any increased pressure which may exist in these more remotely situated cavities, and thus the bacteria are permitted to continue their harmful work in these particular regions.

Occasionally a case is encountered in which the disease seems to advance by regular stages up to a certain point, and then to quiet down spontaneously; not altogether to a normal condition, but yet to one which gives no cause for any anxiety. Then the local conditions remain apparently unchanged for days or weeks together, growing neither worse nor better. Finally, operative interference reveals the existence of a limited amount of purulent fluid and some pale granulation-tissue in a few of the pneumatic spaces; all active inflammation having apparently come to an end. The most natural explanation of conditions like these is the one which assumes that, in the course of the disease, there arrived a time when the micro-organisms died, either from lack of adequate nutritive material (certain anatomical obstacles having prevented their further advance into new territory) or from poisoning (by some kind of protective serum provided by the tissues or by the blood).

Last of all, there are those rare cases in which both the soft and the bony tissues in the vicinity of the tympanum are extensively invaded and destroyed, in a comparatively short period of time, with little or no accompanying pain.

A personal idiosyncrasy in regard to impressions which ordinarily produce the sensation of pain might be assumed in explanation of these rare cases; but it seems to me more natural to assume that we are dealing here with some special variety of streptococcus—one that has the power of creating a substance (a ptomaïne) which possesses anæsthetizing properties.

We do not need to dwell here upon the injurious effects which a run-down state of health or insalubrious surroundings may exert upon the course of an acute suppurative inflammation of the middle ear. Influences of this nature seem to diminish the patient's power of resistance, and thus indirectly to aggravate the severity of the attack.

4. Circumstances under which an Acute Suppurative Inflammation of the Middle Ear Develops.

An acute suppurative inflammation develops in the middle ear under a variety of circumstances. For example, it is of frequent occurrence in connection with the exanthematous fevers (measles and scarlet fever). It is not a rare complication in nasal and pharyngeal diphtheria, in smallpox, in epidemic cerebro-spinal meningitis, in typhoid fever, and in the grippe or epidemic influenza. The so-called "cold in the head" is now and then followed by an acute suppurative inflammation of the middle ear, and bathing in salt water sometimes leads to the same result. The different methods of flooding the nasal passages with remedial solutions or even with simple water are all liable to produce such an acute otitis media. Among the rarer causes I may mention heat prostration and the introduction of the vapor of chloroform and ether into the middle ear by means of the Eustachian catheter. While it is held by some authorities that it is not an unusual thing for a diffuse inflammation of the external auditory canal to spread to the middle ear, I am confident that this event happens only

in those rare cases in which a gouty inflammation first attacks the skin of the meatus and then gradually involves the neighboring bony and soft tissues of the mastoid process and tympanic cavity. On the other hand, it very often happens that a diffuse inflammation of the inner half of the auditory meatus involves at the same time the entire dermoid surface of the tympanic membrane. It is highly probable that it is the observation of this latter fact which has led to the supposition that the tympanic cavity was also involved at the same time. That such a supposition, however, is incorrect, is shown by the absence of tinnitus, of pain, and of any but the most trifling interference with the hearing.

In young children, and sometimes also in adults, the presence of hypertrophied lymphoid tissue in the vault of the pharynx predisposes them in a decided manner to attacks of acute suppurative inflammation of the middle ear. In such individuals the simplest "cold in the head" is likely to be followed by a severe inflammation of this nature; and if they happen to contract scarlet fever or measles, a middle-ear inflammation may be anticipated as something almost certain to take place.

5. Symptomatology.

The development of pain in the ear is the most striking, if not the first symptom noticed by the patient. In infants, and even sometimes in children two or three years of age, the physician is often puzzled to know what ails the child; and the first hint that he receives with regard to the real cause of the patient's fretfulness and feverish condition is that afforded by the appearance of a slight discharge at the outer orifice of the ear. Teething is very apt to be assumed as the cause of the fever, and thus many a case of severe inflammation of the middle ear is allowed to run its destructive course unrecognized, and consequently unchecked.

Then again, in certain cases, the disease may gain considerable headway through another cause. There is a widespread belief in the public mind that an "earache" is something which is quite harmless and entirely different from a genuine inflammation of the ear. This belief is favored by the well-recognized fact that the great majority of earaches spontaneously subside without inflicting any harm either upon the ear or upon the general health of the individual so affected. It is therefore easy to understand how several days may elapse before the parents deem it necessary to seek professional aid.

Upon the development of a perforation, the patient often experiences marked and speedy relief. "I felt something give way in the ear, a watery discharge appeared, and the pain soon subsided," is a statement which one often hears patients make. In many cases, however, the rupture of the membrane affords little or no relief. This is probably due, in many instances, to the insufficient size of the outlet. As the pus can only escape under considerable pressure, when the perforation is small, the tension, which is the chief cause of the pain, continues, and the patient of course experiences little or no relief from his suffering. Among the symptoms of minor importance may be mentioned: a sensation of fulness and sometimes of throbbing or pulsation in the affected ear, subjective sounds of various kinds, such as roaring, singing, whistling, etc.; more or less marked impairment of hearing in the affected ear; increased pain when the jaws are opened and shut; tenderness on pressure over the orifice of the external auditory canal, etc. The two last-named symptoms indicate that the inflammation has spread from the middle ear to the outer meatus. All these symptoms may then gradually subside, and in the course of ten days or two weeks from the onset of the disease the patient may be quite well again and free from all symptoms referable to the ear. Such an attack, in the course of

which no alarming symptoms manifest themselves, may be designated as one of moderate or average severity.

6. Sequelæ and Complications.

In the majority of cases an acute suppurative inflammation of the middle ear runs its course without doing any great amount of damage to the organ of hearing, and without involving any of the structures which lie outside the domain of the tympanum proper.

In a very considerable minority, however, a less favorable termination takes place; and this is particularly apt to happen when the inflammation grows out of a severe attack of measles, scarlet fever, nasal diphtheria, or the grippe. In these diseases an actual destruction of tissue often takes place in some part of the middle ear before the attending physician discovers that anything wrong is going on in that organ. Or, as happens in rare instances, the same unfavorable result may occur even when the disease of the ear is discovered at a very early stage and is vigorously and intelligently treated. But, whatever may be the circumstances under which the destruction actually takes place, a localized bone caries is almost sure to be the immediate result; and from this, in turn, various pathological processes may develop. Thus, for example, we may have, as the most frequent result, a chronic suppuration of the middle ear; while in the exceptional cases a mastoid inflammation, a meningitis, a thrombosis of the sigmoid sinus, or, at least, a periphlebitis of this vessel, may represent the ultimate issue of the original ear disease. As these sequelæ or complications of an acute suppurative inflammation of the middle ear are matters of prime importance, I will consider them more fully in a separate chapter.

The participation of the cervical and post-auricular glands in the inflammatory process is a common event in quite a large proportion of the cases of acute purulent

inflammation of the middle ear. In the uncomplicated ones, however, I have never known this sympathetic inflammation to go beyond the point of producing a moderate degree of swelling and tenderness of the affected glands. It is only in cases in which the mastoid cells are seriously involved that suppuration of these glands takes place; and, even under these circumstances, we cannot be sure that the trouble is not a cellulitis rather than an adenitis.

7. Diagnosis.

When a physician is called to see a patient whose middle ear is only just beginning to be inflamed, he will at first be obliged to limit his diagnosis to the simple fact that an inflammation is going on in that particular portion of the ear. It is only after the disease has advanced further in its course that he can classify it as a catarrhal or a suppurative attack. Occasionally there is some difficulty in determining whether it is the middle ear or the external auditory canal which is the region primarily affected. If the disease has not progressed so far as to involve the external auditory canal to a marked extent, it is scarcely possible to err in our diagnosis. Even without actual inspection, the patient's account of the attack—in the case of an adult—generally gives us some idea of what particular part of the ear is the seat of the inflammation. Actual inspection of the parts, however, can scarcely fail to remove the last element of doubt. I can think of but three possibilities of error: first, an inflammation of the soft parts lining the osseous portion of the external auditory canal and the outer aspect of the drum-membrane may easily be mistaken for an acute inflammation of the middle ear that has involved (secondarily) the inner half of the meatus; then, in the next place, the whitish appearance of the dermoid surface of the drum-membrane, concealing perfectly—as it often does—the underlying inflamed tissues, may mislead an in-

experienced observer into the belief that he is looking at an opaque, thickened, and uninflamed membrana tympani; and, finally, it is possible to mistake a deep-seated abscess of the posterior fold for an acute inflammation of the middle ear. The first error can only be avoided by a careful sifting of all the evidence. An acute inflammation of the middle ear causes more decided deafness and far more pain than does an inflammation of the osseous portion of the canal. Again, the order in which the different symptoms have followed one another furnishes us with valuable aid in deciding which of the two diseases is the one that is under observation in any given case. To avoid the second error, it is simply necessary to demonstrate, by actual manipulation of the parts—that is, by the use of the slender probe, the curette, or the cotton-carrier, armed with a small mop of cotton—that the surface under observation is a part of the living tissues, and not a pasty, dead exfoliation.

The third opportunity for error is afforded by that rare pathological process—a suppurative inflammation in the depths of the soft tissues which constitute the so-called "posterior fold." The great rarity, however, of this pathological process justifies me in ignoring it wholly in the present place.

In cases of fracture or diastasis along the line of the Glaserian fissure there is at first a localized area of redness and swelling in the region of Shrapnell's membrane. The previous history of a fall or a blow, however, would prevent the possibility of interpreting this picture in any other than the right way.

In infants and young children we must rely almost entirely upon what we can ascertain by actual inspection. The mother's account of the symptoms observed is usually, at best, very vague. On the other hand, primary acute affections of the meatus are not so very common at that early period of life.

If we limit our diagnosis, in the class of cases under consideration, to the mere determination of the locality in which the inflammation is going on, our task—judged from the standpoint of practical utility—is but half completed. In order to treat the case intelligently and successfully, we should push our researches much further. We should have before our minds, for example, a reasonably clear picture of the limits of the inflamed area and of the amount of damage already done by the disease. The color of the drum-membrane, the extent to which it is disfigured, the flatness or rotundity of its movable portions, especially its posterior half, and the degree of inflammatory disturbance in the adjacent cutaneous walls of the canal, all furnish valuable means of estimating the degree of vigor displayed by the inflammation, and the degree of tension or pressure to which the soft parts lining the middle ear are being subjected. Having ascertained these facts with more or less accuracy by direct inspection, our next step should be to learn, if we may, to what extent the inflammation has spread from the tympanic cavity to adjacent parts. Has it extended in the direction of the cranial cavity? The severity of the pain in the head, on the same side as that of the affected ear, affords a rough means of measuring the degree to which the congestion of the adjacent meningeal vessels has progressed. Vomiting may also be interpreted as signifying a suspicious degree of meningeal hyperæmia. Has the inflammation spread to the mastoid region? Pain referred to this region, redness and perhaps swelling of the skin covering the mastoid process, and tenderness on pressure with the finger—these are the symptoms which indicate that the mastoid process is participating in the inflammatory process. In this same group of symptoms may be placed another, *viz.*, redness and swelling of the posterior and upper wall of the meatus, in the immediate vicinity of the drum-membrane. Finally, the determina-

tion of the patient's body temperature may serve to confirm the opinion that we have formed from the other methods of examination employed. In children we may confidently expect to find an appreciable elevation of the body temperature in all cases of acute inflammation of the middle ear; in adults we also usually find some elevation of the body temperature, but, as is now well known to be a fact, this elevation is often absent or else it is markedly disproportionate to the serious character of the damage that is being wrought in and around the ear, and particularly in the cranial cavity. It is therefore unsafe in adults to infer, from the insignificance of the rise in temperature or from its remaining normal, that the case is progressing well and that no harm need be feared.

The existence of a perforation may be learned by direct observation or by auscultation while air is being forced into the middle ear. If the perforation is small, or if the membrane has not been thoroughly dried with the mop of cotton-wool, it may be impossible to distinguish the situation of the perforation by simple inspection. As a rule, we can readily discover the point of rupture in such cases by asking the patient to perform Valsalva's experiment while we watch the behavior of the drum-membrane. Even then the perforation may be so small that we can simply distinguish the oozing of a little fluid from a certain portion of the drum-membrane. With the slender probe, however, we can always demonstrate the precise spot occupied by the opening. The presence of fluid exudation in the external auditory canal is not to be taken as satisfactory evidence of the existence of a perforation. The fluid may be, and very often is, simply an exudation from the outer surface of the drum-membrane and adjacent inflamed walls of the canal.

8. Prognosis.

Enough has already been said in the preceding paragraphs to show that it is not possible, even for an expert, to predict, at the onset of an attack of acute inflammation of the middle ear, or even after it has made some advance in its course, what the ultimate issue is likely to be. At the same time it is always permissible to draw encouragement from the fact that the great majority of such attacks terminate favorably.

The physician is often asked to state the probable duration of an attack of acute inflammation of the middle ear. The answer must of course depend upon the severity of the attack, upon the age and condition of health of the patient, upon the degree of inflammation and hypertrophy of the naso-pharyngeal mucous membrane, upon the exciting cause of the disease, upon the surroundings and mode of life of the patient, and upon various other circumstances too numerous to mention. Assuming that all these circumstances are favorable, we may estimate the probable duration at from ten days to three weeks in the cases of average severity, and at from four to six weeks in those of a more virulent type. In young and healthy children recovery takes place more quickly than in adults. In persons who have passed the middle period of life, the return to a healthy condition of the parts is apt to be slow. In individuals of a consumptive type our prognosis, especially with regard to the duration of the subsequent discharge from the ear, must be very guarded. In these individuals the mucous membrane of the middle ear seems to possess little or no recuperative power, and the discharge may continue for weeks or months, in spite of our best efforts to arrest it. In cases of acute inflammation of the middle ear following scarlet fever or measles we must expect a less prompt recovery,

as a rule, than is generally observed in cases which owe their origin to a "cold."

9. Treatment of the Earlier Stages.

The therapeutic task which confronts us in this form of disease, at least in the earlier stages, is of a threefold nature: there is at first an abnormal fulness of the blood-vessels to overcome; then, later, there is developed an abnormal degree of pressure upon all the structures of the middle ear, and this pressure requires to be terminated as soon as possible; and, finally, from the first to the last of the attack, there are pathogenic micro-organisms, the complete destruction of which would doubtless quickly rob the disease of all its harmful elements.

(*a*) *Measures Directly Antagonistic to the Bacteria.*—Inasmuch as the main horde of these organisms is actually in the interstices of the tissues of the mucous membrane, it will be appreciated how nearly powerless we are to destroy them or to hinder them from doing further harm. There are at least some grounds for believing that the charging of the circulating blood with a certain amount of mercury—by administering it internally in the form of repeated small doses of calomel—does exert some kind of a restraining influence upon the invading bacteria. On the other hand, the mere destruction of those which are present upon the surface of the mucous membrane, or in the secretions of the tympanic cavity, counts for little or nothing.

(*b*) *Measures for Reducing the Hyperæmia.*—As I have already stated in section 3 of the present chapter, an active circulation of the blood offers a serious obstacle to the advance and the destructive power of these organisms; and, in order to obtain such an activity of the circulation, we must remove or diminish the hyperæmia, this condition being incompatible with an active circulation.

The measures which have been found more or less effect-

ive in diminishing hyperæmia of the middle ear are the following: the application of either heat or cold to the region of the ear, local bloodletting, paracentesis of the membrana tympani, and bodily rest, or avoidance of physical exercise.

Both *heat* and *cold*, if of moderate degree, cause contraction of the muscular elements of blood-vessels; that is, they are vaso-motor stimulants. They have both been largely used in the treatment of an acute inflammation of the middle ear, and, on the whole, with a fair measure of success. A moderate degree of heat (say between 105° and 110° F.) often diminishes the pain in the ear very noticeably. Inasmuch, therefore, as this agency possesses no anæsthetizing properties, it must effect this result through a diminution of the intratympanic pressure, and this latter it accomplishes by causing a large number of small blood-vessels to contract. When a moderate degree of cold (that of ice water, for example) is employed in the place of heat, an equally good or perhaps even a better result is obtained—at least so far as the relief of the pain is concerned. Many claim that it rarely fails to relieve this symptom; and I am disposed to believe that this statement is true. Unlike heat, cold possesses decided anæsthetizing properties, and consequently it is reasonable to suppose that if the degree of cold employed be sufficiently low, and if the duration of the application be adequately long, the desired benumbing effect must certainly be produced. How far the vaso-motor stimulating effects of this remedial measure contribute to the relief of the pain, is a matter of uncertainty. The practical working of these two agencies is, therefore, about as follows: heat relieves the pain solely through its action as a vaso-motor stimulant—that is, through the diminution in pressure (upon sentient nerve fibrillæ) which results from the contraction of dilated blood-vessels; cold, on the other hand, may relieve the pain in precisely the same manner, but it is more likely that it accomplishes this

result through its power to anæsthetize the irritated nerve fibrils. There may be times when the mere relief of pain is the question of paramount importance, and then doubtless cold should be selected by preference; but when the arrest of the disease and the prevention of serious complications take precedence over all other considerations, heat should be preferred to cold. It may fail to relieve the symptom of pain or to alter the course of the disease, but in this very failure we obtain information of decided value, *i.e.*, we learn—as perhaps, in a given case, we may not learn in any other way—that the disease is advancing. Cold, on the other hand, will probably relieve the pain, and thus we may easily be led into believing that the advance of the disease has been checked. Experience has taught us, however, that the disease often continues to advance even when the cold applications are kept up faithfully for many hours, and are perfectly successful in subduing the pain.

A simple and yet very effective method of applying heat to the middle ear and neighboring regions is the following: While the patient is lying upon the opposite side, with the affected ear turned upward, fill the external auditory canal of the latter with hot water (about 105° F.). Then place immediately over the ear a hot flaxseed-meal poultice (five or six inches square and fully half an inch in thickness) and spread a folded shawl or blanket over the whole, in order to prevent the heat from being dissipated too rapidly. As water is a good conductor of heat, that which fills the meatus may rightly be considered as an arm of the poultice which extends down to the membrana tympani itself.

The *abstraction of blood* from regions which border closely upon the inflamed area may be effected by means of simple incisions, by the application of leeches, and by means of either the Heurteloup artificial leech or the apparatus devised by Dr. Gorham Bacon, of this city.

Medicinal leeches should be applied to the skin just in front of and below the tragus and as close to it as possible. The region immediately behind the auricle is perhaps even preferable to this, at least so far as effectiveness of the bloodletting is concerned. But there is a good reason why leeches should not be applied to the latter region. The leech-bites remain as sore spots sometimes for a period of several days, and consequently if we desire to ascertain whether there be any tenderness on pressure over the mastoid region, we shall not be able to determine surely—in the event of our finding any such tenderness—how much of it is due to actual inflammation in the underlying bone and how much to these superficial sore spots.

Both leeching and poulticing are procedures which, if they happen to be used at the right moment, are competent to turn the scales in favor of recovery. But where the inflammation has acquired a certain momentum—if I may use such an expression in speaking of a bacterial invasion—neither the one nor the other is likely to effect more than a brief delay in the advance of the disease.

The main object of establishing an artificial opening in the tympanic membrane (*paracentesis of the membrana tympani*) is to secure free drainage, and so to put an end to the pressure which is harmful to the mucous membrane and other structures of the ear in a variety of ways. For example, this pressure interferes with the circulation, and so threatens the life of the tissues pressed upon. It also facilitates, as I have already before stated, the advance of the bacteria deeper and deeper into the surrounding parts. Hence, the sooner this little operation is performed, after evidences of intratympanic pressure are discovered, the better for the welfare of the patient, and the sooner is he likely to be relieved of his pain. At the time when the paracentesis is made, the mucous membrane lining the tympanic cavity is usually in a very much swollen and congested

condition. A number of small blood-vessels, therefore, are quite sure to be divided as the point of the knife passes over the opposite promontory. Hence paracentesis of the tympanic membrane must be classed not simply as a measure for securing better drainage, but also as a very direct and powerful agency for diminishing hyperæmia of the middle ear.

The two principal *indications for incising the drum-membrane*, in the course of an acute otitis media, are: undue outward distention or marked hyperæmia and infiltration of the posterior half of this membrane (usually the only part which is fairly visible). Either of these two conditions—*when associated with the symptom of pain*—calls for the operation of paracentesis.

In infants and in adults it is generally practicable to perform this operation in a satisfactory manner without the aid of a general anæsthetic, but in young children and youthful subjects it is not advisable to attempt it without such aid. The local application of cocaine has proved unsatisfactory as a means of anæsthetizing an intact membrana tympani.

It is not necessary that I should give here a description of this little operation. It will be sufficient if I state that the incision, which requires the use of a sharp-pointed, narrow-bladed knife with a long and slender shank, should be made in a curving direction, in the posterior and lower portion of the tympanic membrane, as shown in Fig. 54. There is only one serious danger connected with the operation: the point of the knife may strike the stapes or the long process of the incus, and the hearing may thus be damaged through a disturbance of the stapedio-vestibular attachments.

Bodily rest and *avoidance of physical exercise* will be found helpful in bringing about a diminution of the hyperæmia in the middle ear. The patient's diet should be of a

simple character, easily digestible, and he should abstain wholly from alcoholic drinks.

Almost from the very beginning of the attack it is desirable to have *systematic douching with hot water* employed. By means of this procedure several desirable things may be accomplished. In the first place, exfoliation of the superficial layers of the skin, both on the membrana tympani and throughout the inner half of the meatus, is almost sure to take place toward the end of the first stage of an acute suppurative attack; and the douching, if done with a fair degree of force, will loosen and carry away these masses of cast-off epithelium, and so prevent them from obstructing the escape of the purulent fluid through the perforation in the drum-membrane. In the second place, when the discharge is not very active, it is apt, through stagnation, to undergo decomposition to a greater or less degree. Decomposed pus possesses acrid properties, and consequently when it is in this condition it tends rather to perpetuate the already existing inflammation. The hot douching, repeated at suitable intervals, does not allow sufficient time for decomposition, and so, by means of this procedure, the evil in question is done away with entirely. Finally, the hot douching does excellent work as a vaso-motor stimulant, causing contraction of the paretic blood-vessels of the middle ear.

FIG. 54.—Diagram Showing where the Membrana Tympani should ordinarily be Incised. The dotted lines, in the upper and posterior quadrant of the membrane, indicate where the long process of the incus and the posterior crus of the stapes are located. The heavy black line, which curves downward and forward from just below the stapes, corresponds to that which the knife should follow.

In a very large percentage of the cases of acute suppurative inflammation, this douching with simple hot water or with water which has first been boiled and then allowed to

cool to the proper temperature (about 105° F.)—repeated three or four times a day at first, and then employed with gradually decreasing frequency—constitutes all the local treatment that is required.

The choice of instrument and the mode of carrying out the douching are by no means matters of small importance. Indeed, if personal attention be not paid to these points by the physician, it is more than likely that in a majority of instances the injected stream of water will either not reach the tympanic membrane at all, or else it will play upon it too feebly. Such unsuccessful douching may be explained in the following ways: in some instances the diameter of the nozzle is too great, and for this reason it cannot be introduced far enough into the auditory canal; in other instances, the nozzle may be slender enough, but the mother or the attendant is afraid of injuring the drum-membrane, and consequently the nozzle is not pushed far enough into the canal; finally, in still other instances, the nozzle is both rightly constructed and rightly introduced into the meatus, but the amount of force imparted to the injected column of

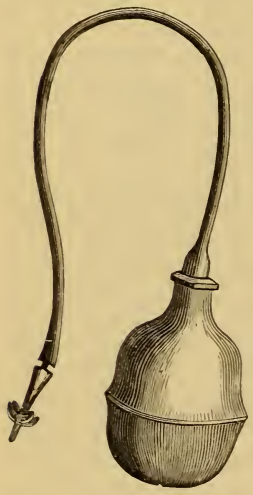

FIG. 55.—Angelo's Ear-douche. (¼ actual size.)

FIG. 56.—Nozzle of Angelo's Ear-douche. (Actual size.)

water is not sufficiently great. The apparatus which is known as "Angelo's ear-douche"[1] and which is described in the foot-note below, diminishes very materially the difficulties which I have just mentioned.

The attending physician should, in every case, personally superintend the douching when it is done for the first time, and he should satisfy himself that the person to whom the task is entrusted is competent to perform it efficiently.

10. Treatment of the Later Stages.

After the simple douching with hot water has been tried for one or two weeks without effecting a complete arrest of the discharge, it becomes plain that we can no longer trust to this measure alone, but must employ something more effective. If our diagnosis is correct—that is, if the disease has now reached a stage in which the only lesion to be overcome is a paretic condition of the tympanic and tubal blood-vessels—a solution of silver nitrate, this most effective of vaso-motor stimulants, should be brought in contact with the affected mucous membrane. There is practically only one way in which this can be accomplished; that is, by forcing the solution through the opening in the membrana tympani into the middle ear. If the perforation is not a mere pinhole, the following method of accomplishing this may be adopted: The fluid contained in the tympanum having been driven out into the external meatus by Politzer's

[1] This douche consists of four parts, all easily removable, *viz.* : a white rubber bulb or reservoir, a hard-rubber stem to fit into the neck of the bulb, a piece of soft-rubber tubing about eight or ten inches long, and a terminal pronged ear-nozzle. The latter is made of hard rubber, and is provided with four prongs which are symmetrically placed around the nozzle, each at a distance of about half an inch from the free end. The diameter of the nozzle at the tip is three and one-half millimetres; at the bases of the prongs it is about four millimetres. The prongs themselves project about six millimetres from the sides of the nozzle, and they are inclined a little backward, away from the tip. (See Figs. 55 and 56.)

method of inflation, and the latter region having been thoroughly cleansed and dried, the patient should hold his head in such a position that the affected ear shall be turned upward. Several drops of the remedial solution, which does not require to be warmed, should then be introduced into the external auditory canal; after which the physician should pull the auricle away from the patient's head with one hand, while with the forefinger of the other hand he should press the tragus backward in the same manner as he would shut the lid of a box. When this has been accomplished he should (while relaxing his hold upon the auricle) press the tragus slowly and firmly inward toward the drum-membrane. In this way quite a strong pressure can safely be brought to bear upon the silver solution that lies upon the outer side of this membrane—a pressure usually sufficient to force a large part of it into the tympanum and on through the Eustachian tube. It is well, however, not to trust to this pressure alone, but to take advantage of the aid which the patient (if an adult) is able to afford by performing the act of swallowing (with or without simultaneous closure of the nasal orifices). When I resort to this method of forcing fluid into the middle ear, I make it a rule to lessen the pressure the moment the patient experiences either pain or dizziness. I also cease to make pressure as soon as the patient notices that some of the solution has reached the naso-pharyngeal space. The final step in the procedure is to remove, by syringing, the surplus of silver solution remaining in the external auditory canal. It is neither necessary nor desirable to expel from the tympanum any of the solution which may happen still to be present in that cavity.

The strength of the silver solution should not exceed one per cent. (5 grains to the ounce of distilled water); and when it is employed for the first time in any given case, it is better that it should be somewhat weaker (2 or 3 grains

to the ounce). Oftentimes a single application of the remedy in the manner described suffices; but if the secretion in the tympanum is even slightly mucoid in character, it is likely to interfere materially with the action of the drug (by preventing it from coming in contact with the mucous membrane generally). In that event several applications, to be made at intervals of two or three days, will be found necessary.

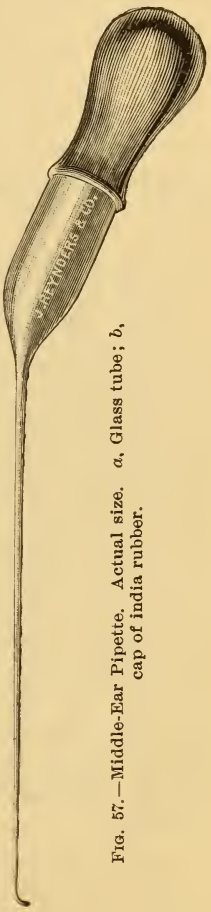

Fig. 57.—Middle-Ear Pipette. Actual size. *a*, Glass tube; *b*, cap of india rubber.

When the perforation in the membrana tympani is a mere pinhole (say, less than one millimetre in diameter), the method described above is not likely to prove satisfactory. Under these circumstances—and personally I should be disposed to add, under all circumstances—it is better to inject the remedial solution by means of an instrument known as "the middle-ear pipette" (Fig. 57). These pipettes are made from glass tubing, five-sixteenths of an inch in diameter and with rather thick walls.

If the perforation is sufficiently large, powdered burned alum may be used in the place of a silver-nitrate solution, and for the same purpose. The mode of procedure is the following: After the middle ear has been freed, so far as this is possible, from the secretion which it contains, and also after the external meatus has been carefully dried, the tip end of a slender silver probe should be slightly moistened, then dipped into the mass of finely powdered

burned alum, and finally carried with its load of the remedial powder into the middle ear. Two or three such loads, if not spilled just as the probe is entering the tympanic cavity through the narrow gateway of the perforation, will usually suffice. As to the general efficacy of burned alum as compared with silver nitrate, I am confident that the latter, when properly managed, is far superior. Nevertheless, one encounters every now and then a case in which the alum accomplishes what the silver solution has failed to accomplish.

11. General Measures which Aid in Effecting an Arrest of the Discharge.

When the local treatment fails to effect the desired cure, we may look for further aid from the internal administration of iron, strychnine, cinchona bark, and cod-liver oil. In young children the syrup of the iodide of iron (10 drops to the dose) and cod-liver oil in teaspooonful doses three times a day will often accomplish the desired result in the course of two or three weeks. In adults, on the other hand, we have, in change of climate, etc., by far the most efficient remedy that we can prescribe for the relief of the obstinately paretic blood-vessels of the middle ear. Children are also markedly benefited by such a change in their surroundings, particularly when their home is in one of our larger cities and they are taken from it to some salubrious place in the country. The greater purity of the air in such a place, as well, probably, as its different character, seems to stimulate the diseased mucous membrane to return to a normal condition.

CHAPTER IX.

CHRONIC SUPPURATIVE INFLAMMATION OF THE MIDDLE EAR.

1. Etiology and Pathology.

In the course of an acute suppurative inflammation of the middle ear various kinds and degrees of damage may be inflicted upon the mucous membrane which lines this system of cavities; and, as a result of the lesions thus established, there will be a discharge which may persist for an indefinite length of time. This mode of origin is the correct one for the great majority of cases of chronic suppurative disease of the middle ear. In a few exceptional instances—those of a tuberculous or a syphilitic origin—the onset of the disease is different. Pathogenic microorganisms of a nature very different from that of most of the bacteria which give rise to the acute suppurative forms of middle-ear inflammation, usually commence their invasion at a comparatively small area of the mucous membrane, and then, in a thoroughly insidious manner, extend their destructive work to surrounding parts. The disease may be said to be chronic from the very beginning.

Inasmuch as the seriousness of the damage inflicted upon the mucous membrane of the middle ear by an acute suppurative inflammation depends largely upon the promptness and effectiveness of the treatment instituted, the lack of such proper treatment may be assigned as the cause of

a very large proportion of the cases of chronic suppurative inflammation of the middle ear.

The simplest and least serious form of chronic discharge from the middle ear is that in which the only demonstrable damage remaining after the subsidence of the original acute attack is the partial destruction of the membrana tympani. In these cases, so far as can be ascertained, no areas of proliferative activity remain in any part of the mucous membrane, nor are there any spots where the bone is denuded of its natural covering. The discharge, which is often of a distinctly mucoid character, is not constant. When investigated more closely, these cases often turn out to be in reality cases of Eustachian catarrh, in which the existence of a perforation in the drum-membrane renders the escape of the secretion by this route easier than by the natural outlet in the pharyngeal vault. The removal of some remnant of hypertrophied lymphoid tissue from the latter cavity is usually all that is required to effect a cure.

Then besides these cases there are doubtless a few—very few, I imagine—in which absolutely the only lesion, in addition to the perforation in the tympanic membrane, is a vaso-motor paresis of the tympanic and tubal blood-vessels. Intratympanic injections of a weak silver-nitrate solution cause the discharge to cease—sometimes permanently, sometimes only for a limited period of time. The favorable result obtained by these injections, however, furnishes good evidence that the cause of the discharge could scarcely be anything more serious than a mere vaso-motor paresis.

The most numerous cases, doubtless, are those in which the discharge has a bad odor, and in which, as a rule, it is possible to demonstrate the presence, in the middle ear, of one or more of the following conditions: bone-caries, granulation-growths, and cheesy or epithelial products. The bone-caries and the granulation-growths are both of them lesions of probably contemporary development—the imme-

diate outcome of the original acute attack. But the cheesy and epithelial products develop at a later date, and their presence affords unmistakable evidence that the mucous membrane is being subjected to some unusual irritating influence. There can be scarcely any doubt that this irritation is supplied by the secretions of the region, which, under the influence of the bacteria of decomposition, have been rendered acrid. In extreme cases a bone-caries, which originally involved only a small area and exerted at most only a slightly harmful effect upon the patient, may eventually, under the favoring circumstances just described, destroy all the bone substance which separates it from a vital part, like the sigmoid sinus, the brain, or the carotid artery; and granulation-growths, under the same favoring influences, may attain an unusually large size. The consideration of these more serious cases will be reserved for a later chapter.

2. Diagnosis.

The physician's chief duty, so far as the diagnosis is concerned, is to ascertain as accurately as possible to just what extent, and in what particular respects, the different parts of the tympanum and neighboring regions are diseased. A thorough cleansing of the external auditory canal must be his first step in the effort to gain this information. Just how this should be accomplished has been stated in detail in chapter I., and it will be unnecessary here to enter into any further description of the conditions which call for the use of this or that particular instrument, or to attempt a description of the proper modes of using them. I will simply formulate two general rules, which will be found, I believe, useful.

The *first rule* is this: When granulation-tissue presents itself to view, it is never safe to assume that the relations are what they seem to be. Thus, for example, I have

more than once thought, after thoroughly cleansing an ear, that the picture presented to my eye was one of a granulating and very much hypertrophied mucous membrane of the inner wall of the tympanum, with total destruction of the membrana tympani. By the aid of simple inspection this was as far as I was able to go in my interpretation of the appearances observed. By gently manipulating the parts with the probe or the curette, however, the incorrectness of my interpretation became at once apparent. The "granulating and hypertrophied mucous membrane of the inner wall of the tympanum" was in reality a flattened polypoid growth, lying upon the outer surface of the drum-membrane. Its peduncle, which passed through a large perforation in the posterior superior quadrant of the drum-membrane, sprang from the upper and posterior portion of the tympanic cavity. Long experience and the most careful scrutiny will never enable the physician to dispense with these instrumental manipulations. And it must be remembered that an error in diagnosis, under circumstances such as I have just described, means also an erroneous plan of treatment.

The *second rule* to which I referred above, is the following: If no fistulous opening is discoverable at any point in the walls of the external auditory canal or in Shrapnell's membrane—that is, in parts which can actually be seen—then we should take for granted that somewhere in the upper and posterior portions of the middle ear—that is, in parts which cannot possibly be examined by the eye—one or more of the following pathological conditions exist, *viz.*, a mass of granulation-tissue, an area of bone-caries, or an agglomeration of cheesy and epithelial débris. The actual demonstration of one or more of these conditions is by no means the uncommon reward of him who, acting upon the above assumption, proceeds to search for them with his slender middle-ear probe and with suitable injections.

There are certain facts which may enable us, in some cases, to direct our search more intelligently, and consequently to reach more easily a correct diagnosis. Thus, for example, if we find that the discharge is escaping through Shrapnell's membrane we may feel reasonably sure that we are dealing with a case in which there is caries of the neck or head of the malleus. If we find a mass of granulation-tissue springing apparently from the posterior and upper portion of the tympanic cavity, we have a right to assume that the chief seat of the disease is in or close to the mastoid antrum. If the amount of the discharge—in the case which I have just supposed—is rather scanty and not particularly bad-smelling, we are warranted in believing that the pathological condition is a bone-caries, of small extent, involving merely the lip of the entrance to the mastoid antrum and perhaps also the short process of the incus, which is fastened to the tympanic wall at this spot. On the other hand, if the accompanying discharge is fairly abundant, and especially if it has a foul odor, we may assume with confidence that some comparatively large area, probably larger than that of the mastoid antrum, must be involved, and that the actual lesion must be a bone-caries, in company with an agglomeration of cheesy and decomposing pus. In both of these carious conditions—that of limited area and that of greater extent—the mass of granulation-tissue at the posterior end of the tympanum points clearly to the fact that pus of an irritating character must be constantly flowing down over this part of the mucous membrane. Finally, if there are granulations which seem to spring from a point directly above the membrana tympani, the vault of the tympanum will be the locality where we may expect to find the lesions which are perpetuating the discharge. If in such a case the incus and malleus have not already been destroyed during the original acute attack, these two ossicles may well be suspected of being affected by caries.

3. Prognosis.

Inasmuch as I have excluded from the present group o_ cases of suppurative inflammation of the middle ear all those in which the disease has already made serious encroachments upon neighboring parts, the prognosis, *so far as life is concerned*, is very good. But under conditions of neglect or of unusual irritation, it is possible for some of these cases to take on a very grave character. In other words, there is a possibility of danger in every case which is characterized by the presence of bone-caries in the middle ear at some point situated at a level higher than that of the upper boundary of the membrana tympani. An area of caries situated at some point lower down—as, for example, at the posterior end of the tympanum or in the floor of that cavity—is not likely to have its drainage seriously obstructed. The statement may therefore be made that the danger, in all these cases, is in direct proportion to the likelihood of the drainage becoming obstructed.

A favorable prognosis may also be made in regard to the *arrest of the discharge* by therapeutic interference.

So far as the *hearing* is concerned, it is only in exceptional cases that we can encourage the patient to believe that it will be rendered more acute. Thus, for example, the removal of granulation-tissue from the vicinity of the stapes will oftentimes effect a very decided improvement in the hearing, but the mere arrest of the discharge does not usually exert a permanently favorable effect upon this function. Indeed, in some instances it distinctly reduces the hearing power—undoubtedly by diminishing the succulency of the soft parts surrounding the foot-plate of the stapes. With the diminution and final cessation of the discharge these soft parts become increasingly dry, thereby losing much of their flexibility; and, as a result of this change, the stirrup, or rather the stapedio-vestibular artic-

ulation, becomes to a corresponding degree anchylosed. Hence, the increased impairment of the hearing, which is apt to be a great disappointment to the patient.

4. Treatment of the Various Pathological Conditions which Favor a Continuance of the Discharge.

The measures which are required in the treatment of the uncomplicated vaso-motor paretic conditions which are sometimes found in cases of chronic suppurative disease of the middle ear have already been set forth in sufficient detail in the preceding chapter. There remain, therefore, for our present consideration the following matters: the removal of a polypoid growth and the after-treatment of the stump; the removal of impacted masses of cast-off epithelium and cheesy débris; and the healing of areas of bone-caries.

(*a*) *Removal of a Polypoid Growth and the After-Treatment of the Stump.*—Very few surgeons at the present time advocate the removal of an aural polypus—*i.e.*, a growth of an appreciable size—by any other than mechanical means. If a large polypus fills the external auditory canal and presents itself within easy reach at the outer orifice, an ordinary dressing-forceps, or, better yet, Hinton's polypus-forceps, will serve the desired purpose as well as any other instrument with which I am acquainted. The mass is firmly grasped between the blades of the forceps, and is then separated from its deeper attachments by a combined rotary and pulling motion, or simply by direct traction. Further on, I will state under what circumstances traction is not to be employed. If the polypus, however, is situated more deeply in the canal, and reflected light is required to render the mass visible, such an instrument as Hinton's forceps—unless the canal happens to be unusually large—will be found awkward to manage, and productive of pain to the patient. Blake's snare (Fig. 58) is the proper instru-

ment to use under these circumstances. By aid of the slender silver probe the physician can ascertain whether the mass grows from the cutaneous walls of the canal or from the middle ear or mastoid cells. Where the growth is of such a size as to fill the canal, it is not necessary that he should satisfy himself of the exact situation of the base of the polypus before applying the loop of wire. It is sufficient for him to ascertain by actual probing that he can pass his snare over the mass to a given depth (distance from the orifice of the meatus) without encountering any obstacle. The loop is then to be pushed in over the mass to this depth and tightened sufficiently to hold the polypus firmly in its grasp. If the growth is succulent and not very firm, and especially if it can easily be rotated about its long axis, steady traction should be made, in the hope of pulling out the polypus, peduncle and all. In not a few cases this object will be attained; but even if the effort fail to remove the entire growth, at least as much of the mass will be torn off as would have been if the wire had been made to cut through the polypus instead of simply grasping it firmly. If the growth is firm in texture and not easily rotated, it is better to use the loop simply as a means of cutting

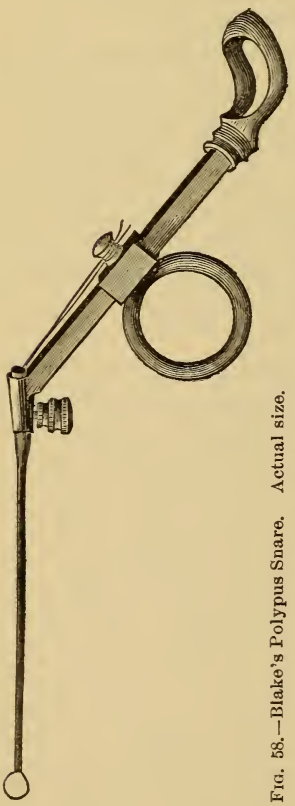

FIG. 58.—Blake's Polypus Snare. Actual size.

off portions of the growth. The same remark applies to the use of Hinton's polypus-forceps. Where the growth is firm in texture and firm in its deeper attachments, traction must not be employed. As soon as the bleeding has ceased, and the portion cut off by the wire loop has been removed with the bent forceps, the remainder of the growth is to be treated in precisely the same way as the first portion. The wire loop is to be applied again and again until the base of the growth has been cut away to the level of the surrounding mucous membrane or skin. If the polypoid mass springs from some portion of the external auditory canal, it will be found as a rule decidedly firmer in texture and more sensitive than one of middle-ear origin. It will also not possess the same degree of mobility as the latter. In polypi of middle-ear origin we shall find that they spring more frequently from the upper and posterior portion of the tympanum (entrance to the antrum) than from any other locality.

I do not know of any *accidents* which are likely to occur in the course of the operation of removing a polypoid growth from the ear. Serious bleeding is very rare.

As to the *treatment of the stump* of the polypus, this must vary according to the spot from which it grows and also according to its length and texture. If the new-growth springs from the malleus or from the posterior end of the tympanum, no great difficulty will be experienced in excising it close to its very roots. The after-treatment of the stump will then amount to little or nothing. Thus, for example, it may be well to touch it firmly for an instant or two with a bead of silver nitrate fused upon the end of a probe; or, instead, a little burned alum may be applied to the cut surface. One thing, however, must always be borne in mind: silver nitrate may easily be applied too freely, and so may be made an agency for the promotion rather than the suppression of further growth. The proper

handling of this drug is something which cannot be formulated in words. Every man must acquire this knowledge by experience. But if the growth originates from some spot which is fairly out of sight, we can scarcely avoid leaving a stump of unknown length; and under these circumstances we shall be obliged to omit all treatment of the stump *per se*.

A few words with regard to the behavior of the stump. After a polypus has been removed, what are the chances that it will grow again? In reply to this question it may be said that if the growth be removed so thoroughly that the cut surface of the stump lies in the same plane as the surrounding fairly healthy mucous membrane, and if at the same time the source of the irritation which gave rise to the growth be also removed, a new polypus is not likely to grow up in the place of the original one. On the other hand, if the source of the irritation be permitted to remain, a new-growth will almost certainly develop from the stump of the old one; and occasionally—fortunately, not often—the seemingly thorough removal of the polypus and the arrest of the irritating discharge fail to stop the further sprouting of the stump. This occasional occurrence suggests the idea that after the tissues—as in the case of the stump of the polypus—have once acquired the habit of growing, of proliferating, they may, in exceptional instances, continue to manifest this habit spontaneously—that is, without the stimulus of an irritant operating from without.

(*b*) *Removal of Impacted Masses of Cast-Off Epithelium and Cheesy Débris.*—The performance of this task constitutes by far the most important part of the treatment in the large majority of cases of chronic suppurative inflammation of the middle ear. The stagnation and the decomposition of the products of inflammation may be considered as the very fountain-head of the chronic discharge. When,

therefore, we have once succeeded in removing all decomposing products from the recesses of the middle ear, and in destroying the bacteria which have given rise to this decomposition, we may confidently expect to see all discharge from the ear cease.

In a small number of cases the mere practice, on the part of the patient, of faithfully douching or syringing the ear once or twice a day, proves to be sufficient to accomplish the purpose desired. It is safe to assume that such a favorable result can only be attained when the processes of decomposition are confined to the lower part of the tympanic cavity—the only part that can be reached and effectively cleansed by the stream of water which escapes from the douche or syringe. In the majority of cases, however, the decomposing products are entirely out of the reach of any douche or syringe which the patient or ordinary unskilled attendant can use. The vault of the tympanum and the mastoid antrum are the two regions in which this cleansing is generally needed, and, to reach these portions of the middle ear effectively, special procedures and instruments are necessary. In the first place, it is self-evident that the most effective way of removing the offending materials which are packed away in these two regions is to wash them out by means of a sufficiently strong stream of water or other fluid directed against them. But, before we can do this successfully, it is often necessary to overcome certain obstacles which stand in our way. The simplest problem of this character is that in which the posterior half, or at least the posterior superior quadrant, of the tympanic membrane and the entire incus are destroyed, thus leaving us unimpeded access to the mouth of the antrum and the greater part of the vault of the tympanum. While our eyes cannot penetrate into this dark upper chamber, the suitably bent end of a slender probe can, and by its aid we may be able to ascertain whether the materials imprisoned

there are of a soft nature, such as may be dislodged by a well-directed stream, or tough and firmly packed, requiring some degree of mechanical force to eject them. In the latter case the bent probe will be found a very efficient instrument for the accomplishment of this purpose; or, if the mass be so firmly attached to the surrounding walls that it cannot be loosened by the probe, we may use in its stead the smaller-sized steel curette, after we shall have given to its malleable shank the requisite degree of curvature. When a channel has once been effected through or on one side of the obstruction, it is a good plan to inject rather forcibly a few drops of hydrogen dioxide (3 per cent.; U. S. Ph.) by means of the glass middle-ear pipette (see p. 125). Such an injection is made, at this stage of the work, not for any disinfecting purposes—although incidentally it will accomplish this also—but simply in order to obtain assistance from the dislodging power which its prompt conversion into bubbles of gas affords. In exceptional cases a single sitting may suffice to clear the vault of the tympanum of all offending materials, but as a rule the operations which I have just described must be repeated a number of times—sometimes for a period of several weeks—before the desired degree of cleansing and disinfection shall have been accomplished. And in carrying out this sort of work it is a good maxim not to attempt too much at one sitting. The cases which yield most quickly are those in which only cheesy and foul débris are accumulated in the vault. In these the injections of hydrogen dioxide very soon effect both a perfect cleansing of the vault of all irritating products and a thorough destruction of the bacteria of decomposition which it may contain. From three to five injections at a sitting may be considered as a sufficient dose. The absence of effervescence in the escaping fluid may be taken as good evidence that a fairly complete disinfection has been effected. The parts are then to be dried, and small quan-

tities of nosophen, aristol, or dermatol are then to be pushed up into the recently cleansed vault. In the earlier stages of this mode of treatment it is well to let the patient carry on systematic douching of the ear; but when the discharge has once been diminished in quantity to such an extent that it can no longer wash away the disinfectant powder which has been introduced into the vault, it is better to stop the douching altogether. The cleansings with hydrogen dioxide and the subsequent applications of the powder constitute, at this stage of the disease, all the treatment that is required.

In addition to the cases such as I have just described, there are some in which we cannot gain a sufficiently free access to the vault unless we excise a portion of the tympanic membrane. This is a very simple procedure, and calls for no special description or instructions. Then, again, there are still other cases in which, in order to gain the necessary amount of space, it is found desirable to excise both the malleus and the incus—or the malleus alone, if the incus, as is often the case, has already disappeared. This operation is termed an *ossiculectomy*.

(*c*) *Treatment of an Area of Bone-Caries.*—The measures which have been set forth in the preceding section are precisely those which are best adapted to effect a cure of a superficial bone-caries. This lesion and the conditions discussed in that section are practically inseparable. A superficial bone-caries in the middle ear is rarely, I believe, a factor of any very serious consequence, if we consider it by itself, apart from the conditions of stagnation and decomposition of pus. I base this belief upon the fact that whenever we succeed in thoroughly cleaning the surface of such a bone ulcer, and in shielding it for a short time (say for a few days) from the irritating influence of the bacteria of decomposition, it ceases to be anything but a passive, a harmless defect. Those cases which seem to be exceptions

to the rule just stated are doubtless cases of more profound involvement of the bone—cases in which more radical measures (than mere cleansing and superficial disinfection) are required for the complete destruction of the bacteria of decomposition. Scraping of the surface of the diseased bone with a sharp-edged instrument or actual ablation of a considerable mass of the part affected will alone suffice to effect this purpose. The mere scraping of the bone is accomplished by means of ring-shaped curettes with sharp edges, or by the aid of sharp spoons of miniature patterns. So far as my own experience goes, I may say that such scraping is called for only in very exceptional cases. The need for employing still more radical measures arises only in a class of cases which do not belong in the present chapter.

CHAPTER X.

MASTOID DISEASE; EXTRADURAL ABSCESS; INFECTIVE THROMBOSIS OF THE SIGMOID SINUS; ABSCESS OF THE BRAIN.

1. General Remarks.

The four diseases enumerated in the title of the present chapter represent the most serious terminations of an acute or a chronic suppurative inflammation of the middle ear. The first three occur rather more frequently in connection with the acute forms of middle-ear inflammation, whereas abscess of the brain is encountered oftener as a late development in the course of chronic ulcerative disease of the antrum or of the vault of the tympanum.

2. Anatomical and Pathological Considerations.

It is only in a very small minority of all the cases of acute suppurative inflammation of the tympanum that the pneumatic spaces which open into it become involved to a decided degree. It will perhaps be worth our while to stop and consider why a serious involvement of the mastoid cells —as these spaces are commonly termed—should be such a comparatively rare event. In the first place, the anatomical relations of these cells, in the adult, are not favorable to the development of an inflammatory process. The antrum is virtually the posterior end of the tympanic cavity, for the passage which leads from the one to the other is, under normal conditions, of fairly large dimensions. Therefore it is reasonable to assume that in every attack

of diffuse inflammation of the tympanum this recess must be involved to an equal degree with the remaining portions of the cavity. Consequently, when acute mastoid disease is spoken of, something more than this participation of the antrum is intended. A close examination of this outlying posterior end of the tympanum (Fig. 59) will reveal to us good anatomical reasons why the great majority of inflammatory attacks do not extend beyond the immediate limits

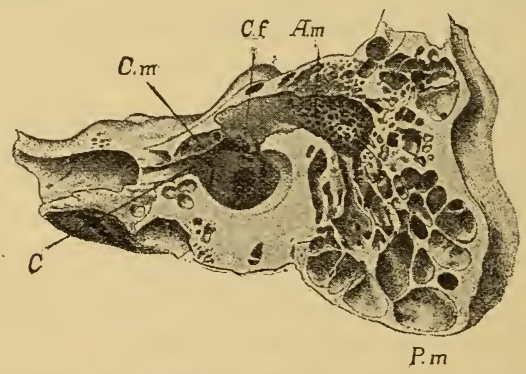

Fig. 59—Section of the Left Temporal Bone, showing the mastoid structures, the antrum, and the inner wall of the tympanum. (After Zuckerkandl.) *P.m.*, Processus mastoideus; *A.m.*, antrum mastoideum; *C.f.*, canalis facialis; between *A.m.* and *C.f.* is located the recessus tegmenti tympani; *C.m.*, canalis pro tensore tympani; *C.*, canalis caroticus in the background of the osseous Eustachian tube.

of this recess. The walls of the mastoid antrum are honeycombed with literally hundreds of minute openings which lead into the adjacent pneumatic spaces—some of them located in the mastoid process proper, others in the mass of bone lying behind the labyrinth, others still in that which constitutes the squamous portion of the temporal bone, and so on. These openings are all so minute that during the preliminary hyperæmia—the first stage of every acute attack of inflammation—the swelling of the mucous membrane must close every one of them. In this narrowness of

the entrances to the mastoid cells, therefore, we have a most serious obstacle to the development, in them, of a suppurative inflammation. But there is still another anatomical factor which tends materially to diminish the total percentage of cases of acute mastoid inflammation. I refer to the fact that quite a large number of individuals have mastoid processes which contain exceedingly few and only scantily developed pneumatic spaces. On this point, Zuckerkandl says that, out of 250 mastoid processes which he examined, he found that pneumatic spaces were wholly lacking in 20 per cent of the specimens, and that perfectly pneumatic mastoid processes, without any diploëtic spaces, represented only 38.6 per cent of the entire number. The conclusion is therefore warranted that there are many individuals whose mastoid processes cannot ever become the seat of a serious suppurative inflammation.

When it is considered that an acute mastoid inflammation represents in reality a more or less successful invasion of these pneumatic spaces by pathogenic micro-organisms which have gained an entrance into the tympanum, it will be readily appreciated that still other factors besides the anatomical ones enumerated above must play a part in diminishing the frequency of acute mastoid disease. Thus, for example, the following factors undoubtedly have some share in promoting or hindering such an invasion of the mastoid cells: the particular kind of microbe which has invaded the tympanum; the duration of increased intratympanic pressure; and the degree of defensive power possessed—at the time of the attack—by the mucous membrane of the middle ear.

In the case of infants or young children, a recognizable degree of involvement of the mastoid process is encountered relatively more often than it is in adults; and, as a rule, it is a complication which, in these little patients, is far less serious in its nature. A study of the anatomical relations

shows readily why these statements are likely to be true. At birth, and even during the first year of life, the mastoid process consists of a small, flattened tuberosity which contains only one pneumatic cell of material size, *viz.*, the antrum (see Fig. 60). This cavity lies very close to the outer surface of the bone, and, besides, the latter is often perforated at this point by one or more minute channels for the transmission of small veins. Sometimes also an emissary mastoid vein of appreciable size traverses the thin wall of bone at or near this point, and thus affords an easy outlet for the products of any inflammation which may take place in the adjacent antrum. In any case of a young child, therefore, in which all these favoring anatomical factors exist, an ordinary and comparatively mild suppurative inflammation of the middle ear is likely to produce at least hyperæmia and infiltration of the skin covering the corresponding mastoid process; and if at the same time the tympanic membrane happen to be somewhat more resistant than usual, the inflammatory exudation may effect an outlet for itself at this point more easily than through the tissues of the tympanic membrane. In this way, also, a collection of pus may form beneath the skin and periosteum covering the mastoid process. In an infant or a young child, therefore, these manifestations on the outside of the mastoid process must not be looked upon as necessarily indicating a grave and threatening extension of the middle-ear inflammation. They are rather to be taken as evidence that, in the advance of the inflammatory process, the degree of

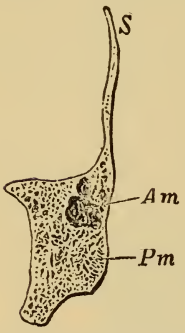

FIG. 60. — Transverse Vertical Section of the Mastoid Process Belonging to a Child Two Years Old. (After Gruber.) *S*, Squamous portion; *Am*, mastoid antrum; *Pm*, mastoid process. (Below and upon its inner side the antrum is surrounded by diploëtic bone substance.)

intratympanic pressure has become so great as to call urgently for the establishment of adequate drainage.

Already at the age of three or three and a half years the mastoid process will be found to be, in all essential respects, almost as fully developed as it is likely to be at maturity. It is only in the slightly diminished size of the process as a whole, and perhaps also in the inferior strength of the bony framework, that it differs from that of adult life. On the other hand, if we compare a number of adult pneumatic mastoid processes we shall scarcely find any two of them alike in the distribution and size of the cells. It is not an exceptional thing to find one or two large pneumatic spaces at the very tip of the process, while those which are situated higher up may be comparatively small. Then, again, in certain skulls the large cells may be distributed in a fairly symmetrical fashion throughout the mastoid bone (Figs. 32 and 59). This same lack of regularity in construction characterizes the location of the sigmoid groove (in which lies the lower part of the lateral sinus), and on the inner and posterior aspect of the mastoid process. At one time—and this is probably true of the majority of cases—it is situated so far back that ample space is left between it and the posterior wall of the external auditory canal for all operative work that may be required. Then, at another time, it encroaches to such an extent upon either the anterior or the external boundary of the mastoid process that great care has to be exercised in operations upon this bone. I remember one instance, for example, in which the lamina of bone that separated the sigmoid sinus from the outer surface of the mastoid process measured not more than one-sixteenth of an inch in thickness. In this case the very first chip of bone removed with the chisel exposed to view the bluish wall of this large vein.

The area of distribution of the pneumatic spaces is a subject which demands some consideration. Superiorly, they

may extend as high as to within half an inch of the temporo-parietal suture. In this comparatively thin part of the temporal bone they are separated, on the outer side

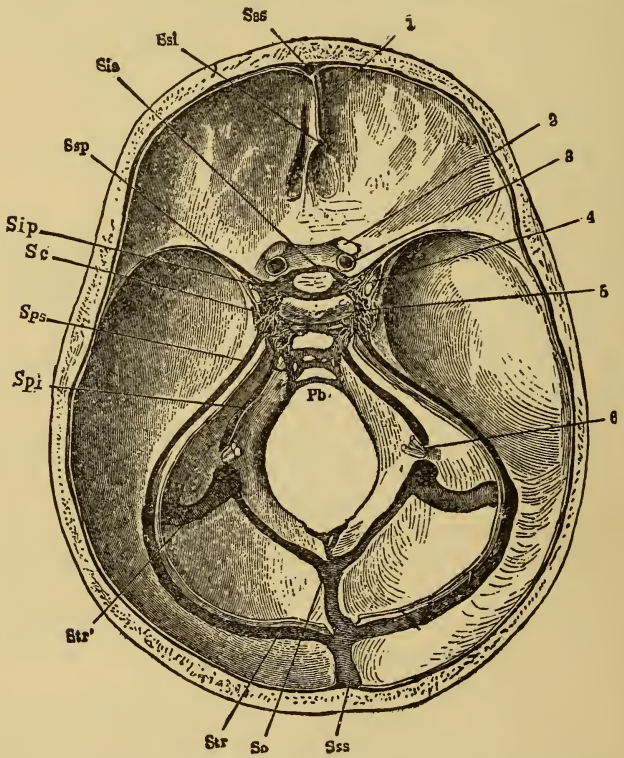

FIG. 61.—Internal View of the Base of the Skull, showing the relations of the venous sinuses. (After Henle.) 1. Horizontal section of the falx cerebri; 2, optic nerve, divided at the entrance into the optic canal; 3, trunk of the internal carotid artery; 4, oculomotor nerve; 5, dorsum of the sella turcica; 6, nerves projecting from the jugular foramen; *Sss*, *Ssi*, the superior and inferior sagittal sinuses, seen in cross section; *Sia*, *Sip*, the anterior and posterior intercavernous sinuses, including the hypophysis between them; *Ssp*, the spheno-parietal sinus; *Sc*, the cavernous sinus; *Sps*, *Spi*, the superior and inferior petrosal sinuses; *Str*, *Str*[1], the transverse sinus, or lateral sinus, or sigmoid sinus; *So*, the occipital sinus; *Pb*, the basilar plexus. (Reduced about ½.)

from the periosteum, and on the inner side from the dura mater, by a dense layer of bone which varies from one to three millimetres in thickness. Anteriorly, the pneumatic cells extend forward over the external auditory canal. Posteriorly, they cease somewhat abruptly, that is, without any material diminution in size in the immediate vicinity of the temporo-occipital suture. Hyrtl, according to the authority of Schwartze, found three skulls (among six hundred which he examined for this purpose) in which the pneumatic cells extended even into the occipital bone.

The *sigmoid sinus* ordinarily occupies a groove in the bone in the immediate vicinity of the posterior limits of the mastoid cells; but, as I have already stated above, the position of this groove varies greatly. The small venous channels in the mastoid pneumatic cells communicate at several points with the sigmoid sinus, and those of the antrum and tympanic cavity pass through the petro-squamous fissure (in the bony roof which covers both of these regions) into the cranial cavity, and pour their blood into the superior petrosal sinus (see Fig. 61). Thus, as it appears, there is no lack of channels along which bacteria may travel to vital parts of the head. Furthermore, the posterior end of the antrum is in very close proximity to the sigmoid fossa, in which lies the extension of the lateral sinus—here called the sigmoid sinus; the distance between the two varying from three to six millimetres. The distance from the outer limit of the antrum to the external surface of the mastoid process varies (in adults) from twelve to twenty millimetres (from one-half to three-quarters of an inch).

The *facial nerve* is another important organ which lies in very close relationship to the antrum and pneumatic spaces of the mastoid process (see Fig. 33). It often becomes paralyzed in the course of a serious inflammation of this region.

In a preceding paragraph I have spoken of the fact that

in a large majority of the cases the acute inflammation does not extend beyond the immediate confines of the tympanum and antrum—or, in other words, that the invading bacteria, in these acute attacks, rarely penetrate into the pneumatic spaces of the mastoid process. But after they have once gained an entrance into these cavities, the conditions which exist there are pre-eminently favorable to their accomplishment of the maximum degree of damage to the tissues.

The *pathological changes* which are found in the mastoid cells at different stages of the disease are the following: marked hyperæmia, enormous hypertrophy of the delicate mucous membrane which lines the spaces, necrosis of the septa of bone, and the breaking down of all these inflamed parts into pus. In addition to these changes, phlebitis and plugging of some of the small veins which are located in the mastoid process may occur, and may eventually lead to phlebitis and thrombosis of the sigmoid sinus, and to a general pyæmic infection. A certain amount of septicæmia is doubtless present in every one of the acute suppurative cases.

3. Symptomatology and Diagnosis.

A. In the Acute Cases.—The different conditions to which the terms "mastoid disease," "extradural abscess," "infective thrombosis of the sigmoid sinus," and "abscess of the brain" are commonly applied are so intimately associated the one with the other, as regards their symptomatology, that I shall make no attempt to treat them separately. In any given case it is impossible to determine at what precise time the inflammation of the ear has over-stepped the strict limits of the tympanic cavity and antrum, nor can one always be sure in what particular direction it is extending—whether backward toward the sigmoid sinus and cerebellum, or upward toward the cerebrum, or simply downward into the body and tip of the mastoid process. Nevertheless,

there are certain symptoms and external manifestations which throw light upon these questions, and enable us, with some approach to accuracy, to determine what course an acute inflammation of the middle ear is pursuing and how far it has progressed along this course.

In order to bring these points out more fully, I will consider here separately and somewhat in detail the relative value of these different symptoms and signs.

(*a*) *Pain.*—In acute inflammation of the middle ear, pain in the mastoid region points to involvement of the pneumatic spaces only when it persists despite the establishment—either by natural processes or by artificial means—of an opening in the tympanic membrane. It is fair to assume that when once an adequately large opening has been provided in this membrane, all increased intratympanic pressure must come to an end; or, in other words, that whatever pain may be due exclusively to pressure in this cavity must then disappear. And it is equally fair to assume that if the pain persists after such an outlet has been provided, it must then be due to pressure upon an inflamed mucous membrane situated outside the tympanic cavity, or, in certain exceptional cases, to pressure upon certain intracranial organs. Thus, by exclusion of one of the two possible seats of the pain, we reach the conclusion that the other—*viz.*, the pneumatic spaces—is the region in which the inflammation is progressing. This persisting or frequently recurring pain may be referred by the patient to the deeper parts of the ear as well as to the region immediately behind it; and oftentimes the occipital region, the side or the top of the head, and even the frontal region, may be complained of more decidedly than either of these two localities. It is not unlikely that these differences in the localization of the pain are due to the varying degrees to which different plexuses of the trigeminal nerve are affected by the neighboring inflammation in the temporal bone.

Finally, when pain persists despite the presence of an ample-sized drainage-opening in the membrana tympani, and despite the fact that operative interference had already removed all possible causes of pain in the domain proper of the mastoid pneumatic cells, we are warranted in suspecting the presence of an accumulation of pus around the sigmoid sinus, between the dura mater and the wall of the skull, or even in the brain substance itself.

On the other hand, one must be careful not to assume, in a case in which there are indications pointing to the existence of mastoid disease, that this diagnosis is erroneous simply because the symptom of pain is lacking. There are cases on record in which the patient made scarcely any complaint of pain, and yet operative interference revealed the existence of advanced disease of the mastoid pneumatic spaces.

(*b*) *Tenderness on Pressure.*—Tenderness on pressure over the mastoid region, when it develops in the course of an acute suppurative inflammation of the middle ear, affords a valuable indication of the spread of the disease to the mastoid pneumatic spaces. I can think of only one other condition in which such tenderness on pressure may develop; I refer to an inflammation of the external auditory canal which spreads backward over the outer aspect of the mastoid bone. If the patient is seen for the first time after the walls of the outer canal have become so swollen that it is no longer practicable to obtain a satisfactory view of the tympanic membrane, the physician will have to depend largely on the history of the case in determining the precise significance of any tenderness or swelling of the mastoid integuments which he may find.

Occasionally a small gland is found lying upon the outer surface of the mastoid process, and this may easily, even in the course of a comparatively mild inflammation of the middle ear, become somewhat enlarged and tender. The

finding of a small movable body under the skin will reveal to us the true explanation of this form of local tenderness on pressure.

It is an important matter, in testing the mastoid region for tender spots, to subject every part of the bone to fairly firm pressure; for it is not a rare thing to find such tenderness on pressure only at some one or two comparatively small spots—as, for example, at the extreme posterior limit, below, or quite deep down upon the anterior aspect of the bone. The conditions found at the time of the operation often harmonize perfectly with the results previously ascertained by such a digital examination; pus being present only in certain pneumatic spaces situated at points corresponding to the spots where tenderness was previously demonstrated to exist. The spot, however, where tenderness is most often and earliest found is situated rather high up and close to the line where the skin is reflected over the back of the auricle. It represents that part of the surface of the mastoid process which lies nearest to the posterior end of the antrum. The significance of tenderness at this spot is, as one would naturally anticipate, much less serious than it is at spots situated farther away from the antrum.

Finally, if a blister, or the tincture of iodine, or leeches have already been applied to the skin behind the ear, as is very apt to be the case, it will not be possible for us to draw any safe conclusion in regard to the presence of tenderness on pressure in the mastoid region; for all of these therapeutic procedures are likely to leave the skin of this region in a somewhat sensitive condition.

Hyperæmia and Œdema of the Skin Covering the Mastoid Process.—If tenderness on pressure develops behind the auricle, this symptom is very apt to be followed in a short time by redness and swelling of the skin in the same region. When these alterations do not appear, we may explain their absence in one of two ways: either the mastoid in-

flammation is of a mild type—a mere hyperæmia of the mucous membrane which lines the pneumatic spaces; or else the tenderness on pressure is not due to the slight inflammatory involvement (through an extension by way of some of the numerous minute vascular channels which exist in the central part of the outer wall of the bone) of the overlying soft parts, but merely represents the pain caused by pressure transmitted through a somewhat elastic wall of bone to the sensitive soft parts within. Redness of the skin is more often lacking than œdema, and the latter may spread throughout a wide area—even as far as to the occiput or the forehead.

(*c*) *Prolapse of the Upper and Posterior Cutaneous Wall of the Auditory Canal in the Neighborhood of the Membrana Tympani.*—If the invading micro-organisms have already succeeded in penetrating beyond the immediate walls of the antrum, the mass of bone which separates the latter cavity from that of the external auditory canal will become—if it be not of too dense a character—at a comparatively early stage the seat of active inflammatory changes; and the outward sign of this osteitis will be a corresponding inflammation of the skin located on the posterior and upper wall of the meatus near the tympanic membrane. On the other hand, if this portion of the temporal bone possess such a dense structure that the bacteria cannot readily penetrate it, the phenomenon which I have just described will not appear, and our estimate of the extent and activity of the neighboring mastoid inflammation will have to depend upon other evidence. In some instances of severe inflammation of the middle ear the periostitis involves the entire osseous portion of the meatus, the swelling of the lining membrane being greatest near the tympanic membrane, and shading off gradually from this point outward. My recollection is, that in the majority of these instances the disease has eventually subsided without giving rise to a serious inflamma-

tion of the mastoid cells; and from this circumstance I am disposed to believe that, as a rule, this symmetrical periostitis has an entirely different significance from that which is localized in the posterior and upper parts of the canal. It represents, I suspect, the effects of a direct invasion of bacteria from the tympanic cavity, while the latter should rather be considered as a mere localized periostitis which has developed in sympathy with the contiguous bone inflammation.

(*d*) *An Abundant Discharge of Creamy Pus through the Opening in the Membrana Tympani.*—This is a very trustworthy indication of suppurative disease of the pneumatic spaces. Such a copious discharge of pus, as one can readily understand, must necessarily come from an area much larger than that of the tympanic cavity; and it must therefore be the mastoid region from which this large quantity of purulent fluid—amounting in some cases to several teaspoonfuls in the course of the twenty-four hours—escapes. Inasmuch as such a free flow of pus cannot possibly take place through the natural channels which lead from the pneumatic spaces to the antrum, we are warranted in assuming that the process of breaking down of the bony septa has already progressed so far as to remove many of those which are located in the vicinity of the antrum, and thus to establish a free outlet for the pus. The period when this change is likely to take place is that of the second or third week of the disease.

(*e*) *Facial Paresis or Paralysis.*—It is only in very exceptional instances that an acute suppurative inflammation of the mastoid cells is associated with any disturbance of the facial nerve, and then, as a rule, the trouble is only of slight degree and of brief duration. When such a paresis, however, does develop, it furnishes good evidence that the inflammation must have involved the pneumatic spaces to a considerable degree.

(*f*) *Extension of the Inflammation to the Soft Parts Below the Mastoid Process; Bezold's Symptom.*—Sometimes the tissues on the side of the neck, a short distance below the tip of the mastoid process, become inflamed and swell rather rapidly into a hard, flattened, and very sensitive tumor. The skin covering this matted cake of inflamed glands and other soft parts lying in front of the sterno-cleido-mastoid muscle is red, œdematous, and firmly adherent to the underlying tumor. This rapid infection of the tissues on the side of the neck is held by Bezold to indicate that some of the inflammatory exudation in the pneumatic spaces has escaped from the lower end of the mastoid process, either through a congenital defect in the bone, or through an opening which owes its origin to a pathological process of softening. Bezold's explanation, which is now generally held to be the correct one, receives strong support from two facts, *viz.*, the simultaneous diminution or disappearance of the pain, and the diminution or even entire cessation of the discharge from the middle ear by way of the perforation in the tympanic membrane.

In the order of development of the different phenomena which may be considered as diagnostic of mastoid disease, Bezold's symptom comes, as a rule, rather late; that is, after the pain, the tenderness on pressure behind the ear, the hyperæmia and œdema of the skin in this locality, and the prolapse of the posterior and upper cutaneous wall at the inner end of the meatus, have made their appearance. The phenomena described here, it must not be forgotten, bear a very close resemblance to those observed in cases of sigmoid thrombosis, with phlebitis of the internal jugular.

(*g*) *Phlebitis of a Mastoid Emissary Vein.*—An area of localized inflammation is sometimes observed, in the course of an acute attack of mastoid inflammation, at one of the following points: directly below and a little posterior to the mastoid process; a short distance behind this bone and a

little above the level of the tip; and still farther back, not far from the occipital protuberance. The possibility that these areas of inflammation in the scalp may be due to phlebitis of a mastoid emissary vein was first suggested, I believe, by Dr. J. Orne Green, of Boston. When such a localized inflammation is encountered in a case which for other reasons is believed to be one of mastoid disease, the phenomenon should certainly be considered as furnishing very strong corroborative proof of the correctness of the diagnosis. Similar areas of inflammation have been observed at points above the mastoid region, even as high up as on the vertex and as far forward as in the temporal region, and their presence in these localities suggests the possibility that the lymphatics may also serve as channels along which the infection is conveyed from the pneumatic spaces to distant parts of the scalp. The possibility of an escape of pus from an extradural abscess through one of the natural openings in the skull, must also be borne in mind in connection with these localized areas of inflammation beneath the scalp. The possible relation to sigmoid thrombosis must also not be overlooked.

(*h*) *Septicæmic and Pyæmic Phenomena.*—While it is scarcely possible for a suppurative inflammation of the mastoid pneumatic spaces to run its course without giving rise to a certain amount of septicæmia, experience shows clearly that this—as expressed by the degree of elevation of the body-temperature—does not bear any fixed relationship to the severity or extent of the suppurative disease. It is only in youthful individuals that we are likely to find this relationship as a prevailing characteristic; but in adults the rise in temperature is often insignificant, even when, through the presence of other signs, we are confident that a severe suppurative disease is in progress. However, cases are encountered in which the behavior of the body-temperature furnishes us with valuable diagnostic aid. Thus, for

example, the persistence of a high temperature after a free opening has been established in the membrana tympani may justly be interpreted—in the absence of any other demonstrable cause—as pointing strongly to mastoid involvement. And yet even in these cases there must be additional evidence before we can safely make a diagnosis of mastoid disease. A persistent high temperature, in conjunction with pain in the region of the ear, with tenderness on pressure over the mastoid region, or with prolapse of the posterior and superior cutaneous wall of the external auditory canal, may be considered as good evidence of the existence of this disease. On the other hand, if this additional evidence is lacking, and especially if the conditions in the tympanic cavity are steadily improving, we should institute a more rigid search for disease in some other part of the body. Among the puzzling cases of this character which have come under my observation, I can recall one in which a beginning pulmonary tuberculosis, another in which an endocarditis, and a third in which a limited pleurisy, explained the persistence of an elevated body-temperature; but in each of these cases the discovery of the true cause was not made by the attending physician until several days of anxious uncertainty had elapsed.

When *pyæmic symptoms* occur—as shown by irregular chills and by the development of metastatic or embolic foci of inflammation in other parts of the body—we may be sure that the disease has passed the stage of a mere suppurative inflammation of the mastoid cells, and has involved to a serious degree some contiguous venous channel. First, periphlebitis, and then phlebitis, with entrance of infected products or of the infecting agents themselves into the venous circulation, are the changes which take place in such cases.

So far as *periphlebitis* is concerned, there are no symptoms which indicate surely that an inflammation of the

mastoid process has extended beyond the inner cortical layer of bone and has excited suppuration around the sigmoid sinus—or, in other words, has set up a periphlebitis in this region. It is only when the interior of this vein becomes involved that we may sometimes infer, from the symptoms then manifested by the patient, that an actual phlebitis has developed.

A high body-temperature with marked fluctuations; pain referred to the region behind the affected ear and to the corresponding side of the head generally; and chills or rigors at irregular intervals, often followed by profuse perspiration, are symptoms which, if they develop in the course of either an acute or a chronic suppurative disease of the middle ear, are universally accepted as indicating the existence of an *infective thrombosis of the sigmoid sinus.* At an early stage of the disease the symptoms enumerated above may be found to be the only indications of the inflammatory process going on in the sinus; but after a certain length of time has elapsed other manifestations will be likely to develop, *viz.*, those due to obstruction of the flow of venous blood through the sinus, and those arising from inflammation of the veins which communicate with it. Thus, when the flow of blood through the cavernous sinus is interfered with, the ophthalmic vein becomes engorged, and, as a result, there will be moderate oedema or puffiness of the eyelids of the corresponding side. Neuro-retinitis is also likely to be associated with thrombosis of the sigmoid sinus.

(*i*) *Symptoms Indicative of the Involvement of the Brain or its Membranes.*—If the products of an acute suppurative mastoid inflammation are not afforded, by surgical interference, a sufficiently early outlet, or if an adequate drainage channel is not established spontaneously through a process of softening of the inflamed bone substance somewhere at the periphery of the mastoid process (*e.g.*,

anteriorly, in the external auditory canal; externally, in the central part of the body; or inferiorly, in the tip), there is great danger that an outlet may form in an upward direction into the cranial cavity. And when this happens, the occurrence will soon announce itself by one or more of the following symptoms: nausea and vomiting, general headache or pain of a more localized character, delirium, convulsions, drowsiness, thick speech, photophobia, strabismus, optic neuritis, dry and heavily coated tongue, and perhaps alterations in the rhythm and rate of the pulse-beat and respirations. In abscess of the brain the pulse rate is often slower than normal, and the body-temperature may be only slightly elevated.

B. In the Chronic Cases.—With very few exceptions—I refer to those of a tuberculous nature—chronic mastoid disease begins originally as an acute suppurative inflammation of the pneumatic cells—an inflammation which is followed by the destruction and melting down of enough bone-tissue adjacent to the antrum to furnish a moderately good drainage channel for the remaining carious area. As a result of this fairly adequate drainage—by way of the antrum, the tympanic cavity, and the external meatus—the patient may, for a period of many years, suffer no distress or inconvenience beyond that occasioned by the persistence of a discharge from the affected ear.

The chronic form of mastoid disease is characterized by certain features which distinguish it very markedly from the acute form. Thus, for example, it seems to be a fixed law that, *pari passu* with the chronic suppurative process near the antrum, a subacute condensing osteitis shall involve all those pneumatic spaces which escaped injury during the original acute attack. This osteitis is characterized by the formation of new bone-tissue, and it progresses steadily, through a period of months or years, until solid, ivory-like bone takes the place of what before was an assem-

blage of air-containing cavities. *Sclerosis or hyperostosis of the outer portions of the mastoid process is therefore a regular characteristic of chronic suppurative mastoid disease.*

This well-established fact in the pathology of chronic mastoid disease has a very important bearing upon its symptomatology. The presence of such an ivory-like wall of bone on the outer side of the focus of suppurative disease offers an impassable barrier to the escape of pus in that direction. In fact, the process of hyperostosis goes so far in these cases that even those channels which, under normal conditions, give passage to numerous small veins, become obliterated. It will therefore be easily understood why those symptoms which have such a great diagnostic value in the acute form of the disease—*viz.*, redness, tenderness, and swelling of the skin in the mastoid region, and redness or prolapse of the skin which lines the superior and posterior wall of the meatus near the membrana tympani—should, as a rule, be entirely lacking in the chronic form. The rare exceptions to this rule may, in some cases, be explained by assuming that the process of hyperostosis had not as yet obliterated all the channels of communication between the neighborhood of the antrum and the surface of the mastoid process. Then again there are still other cases in which an accompanying inflammation of the soft parts of the external auditory canal extends outward and backward to the skin covering the mastoid process, thus giving rise to the symptoms of swelling and tenderness on pressure which a novice might easily attribute to a direct extension of the inflammation from the body of the underlying bone. An error like this, however, can have no possible evil consequences.

Then, in the second place, the *bacteria of decomposition* play an important part in chronic mastoid disease, whereas in the acute form they play no part whatever. By reason of their presence certain highly irritating juices (toxins) are

created in the focus of suppurative disease, and under the provocation of this irritating influence the mucous membrane lining the focal cavity assumes a proliferative activity. At one point, this activity takes the form of a connective-tissue hypertrophy (granulation growths), while at another it goes no further than to cause the shedding of layer after layer of the outermost strata of epithelial cells. Thus, in the course of time, there will be developed, side by side in the same focal cavity of a case of chronic mastoid disease, the following pathological processes: the new-formation of connective tissue, usually limited in extent; the casting off of epithelium in laminated sheets, often to a prodigious extent; the formation of pus, which immediately undergoes decomposition and soon becomes converted into cheesy material; and, finally, the ulcerative destruction of bone-tissue in whatever directions there may still be some which has not undergone the sclerosing change (these directions being almost invariably upward toward the dura mater at the base of the brain, or backward toward the sigmoid sinus). The final ending of chronic mastoid disease is likely, therefore, to be an abscess of the brain, or an infective sinus-thrombosis, or a combination of both these conditions.

Chronic mastoid disease has no characteristic symptoms during the greater part of its course. It is only when the ulcerative process begins to encroach upon the facial nerve, the dura mater, or the sigmoid sinus, or upon some part of the labyrinth, that any symptoms other than that of a foul-smelling discharge from the affected ear make their appearance. The earliest of these is *pain*—referred generally to the side or the back of the head. *Facial paresis* occasionally develops, thus indicating an extension of the area of ulcerative disease in the direction of the facial canal. In some cases *vertigo* is also complained of by the patient; and in two or three of these cases I have had the oppor-

tunity of demonstrating that that portion of the tegmen tympani which lies above the mastoid antrum had been entirely destroyed. Doubtless some little increase of pressure upward against the exposed surface of the dura had, in these particular instances, put the fibres of the ampullar branch of the auditory nerve upon the stretch, and thus had excited the symptom of vertigo. The same increase of pressure in the focal cavity—or chief centre of the disease—is likely to cause a certain degree of *septicæmia*, which will manifest itself by a rise in the body-temperature. Ultimately, the disease may extend beyond the limits of the temporal bone, and in this manner the sigmoid sinus, the dura mater, and even the brain itself may become involved. Under these circumstances *chills at irregular intervals, various abnormal conditions of the eye, localized pareses*, or even a *partial hemiplegia, convulsions, delirium, vomiting*, and finally *coma* may be looked for as evidences of such an extension of the disease beyond the limits of the temporal bone.

Finally among the rare issues of the disease may be mentioned hemorrhage from one of the large blood channels which pass in such close proximity to the middle ear, *viz.*, from the sigmoid sinus or from the carotid artery.

Although ordinarily there is no difficulty in ascertaining the fact that the case in hand is one in which the present attack represents an acute exacerbation of a long-standing disease of the middle ear, there are times when it is a very difficult matter to determine whether we are dealing with such an acute exacerbation or with a *bonâ-fide* primary acute attack—*i.e.*, one that has developed in an ear not previously subject to chronic suppurative disease. The most important point to remember in this connection is the fact—to which I have already called attention—that in an acute lighting up of an old suppurative mastoid inflammation there will

probably be no external manifestations of such an internal acute exacerbation of the inflammation—no redness, no swelling, no tenderness of the skin covering the mastoid process. Indeed, in not a few instances our decision to operate upon the bone is based almost exclusively upon the solitary symptom of pain in the region of the ear—a pain which has developed in or near an ear which has long been the seat of suppurative disease.

4. Prognosis.

Acute suppurative mastoid inflammation, if left to itself or if treated in the impotent fashion which prevailed even as recently as thirty years ago, is a disease remarkably full of disagreeable and dangerous possibilities: such, for example, as a lifelong discharge from the ear or from an external fistulous opening; a permanent paresis or paralysis of the facial nerve; periphlebitis and phlebitis of the sigmoid sinus or the superior petrosal sinus; metastatic abscesses; and inflammation of the membranes or of the substance itself of the brain. We have no means of giving precise figures in regard to this matter, but I believe that I shall not exaggerate the truth if I venture to say that, in the first half of the present century, at least one in four of these acute mastoid cases terminated fatally, whereas at the present time not less than nineteen out of twenty of them make a perfect recovery. All through these years the tendency, on the part of aural surgeons, has been, first, to operate at an earlier stage of the disease, and so to arrest its advance beyond the strict domain of the pneumatic cells; and then, in those cases in which the disease had already involved neighboring structures, to follow it, in their explorative work, to the remotest corners which it may have reached. Aseptic and antiseptic methods have contributed greatly to the success of these bolder and more thoroughgoing surgical measures. Indeed, it rarely happens at the present time

that one can rightly say, in any given case, that the disease has advanced so far that it would be a hopeless task to operate. Brain symptoms, paralyses, and pyæmic manifestations are no longer accepted as evidences that the disease has advanced so far that we may not entertain a reasonable hope of fighting it successfully.

5. Treatment.

(*a*) *In the Acute Cases.*—When an acute inflammation of the mastoid cells does not yield promptly to such simple measures as paracentesis of the membrana tympani, hot poulticing, douching the meatus with hot water, and perhaps, in addition, local blood-letting (leeches, incision of the cutaneous wall of the meatus), the proper course to adopt is to perform what is usually termed a mastoid operation.

In the earlier operations upon the mastoid process, the chief object aimed at was to establish a free opening between the antrum and the outer world by means of a drill or other kind of boring instrument. Despite the manifest imperfections of this method, it proved to be adequately efficient in a large percentage of the acute cases. Prof. H. Schwartze, of Halle, Germany, was the first to recognize these imperfections, and to advocate the more thorough method which is now universally adopted, and which has very appropriately been termed *the Schwartze operation.* The fundamental idea of this more modern operation is to remove every portion of the mastoid process which seems to be affected to a serious degree. For this purpose Schwartze recommends the use of small chisels and gouges, which are to be driven by blows from a suitable mallet; sharp-edged spoons, by means of which the softer cancellous bone structures may be removed; and rongeur forceps. When the operation upon the bone is completed the mastoid antrum will be found at the bottom of a rather shallow

excavation in the outer surface of the temporal bone. This open excavation is packed with aseptic gauze, and the subsequent dressings are conducted in a such a manner that the wound may gradually heal by the growth of granulations from the bottom and sides.

When for any reason—such, for example, as the symptomatology of the case, or the conditions observed in the wound during the progress of the operation—it is suspected that the disease has invaded the cranial cavity, the proper course to adopt is to remove carefully the cortical layer of bone which intervenes between the excavation made with the chisels and spoons, and the dura mater. What the succeeding steps shall be, must depend largely upon the pathological alterations which are brought to view after the removal of this cortical layer of bone. If pus be found lying between the latter and the dura mater (extradural abscess), this must be fully removed and the surrounding parts must be thoroughly irrigated with a suitable germicidal solution. At the same time a further search must be made for areas of diseased bone or for the presence of granulations upon the surface of the dura mater. If it be found that thrombosis has already taken place in the sigmoid sinus, the contained thrombus must be looked upon in very much the same light as if it were pus—that is, as infective material; and not merely as an isolated focus of infective material, but as one which is lying in a large venous channel that leads almost directly to the right chamber of the heart. Consequently this vessel (the internal jugular) will have to be ligated at some point below the thrombus, in order to prevent any of the infective material from entering the heart; and then, after this precaution has been taken, the thrombus itself must be removed by cutting open that part of the vessel which contains it.

Finally, if we fail to find an extradural abscess or an infective thrombus in the sigmoid sinus, and yet are con-

vinced, from the symptomatology, that there must be some lesion which is producing an appreciable increase in the intracranial pressure, our next step must be to make an exploratory puncture into the substance itself of the brain; into the temporo-sphenoidal lobe of the cerebrum, if the appearances discovered in the course of the preceding operative work suggest that as the most likely direction pursued by the disease, or into the cerebellum if the evidence favors that as the more likely route. Furthermore, the possibility of a combination of two or more of these intracranial lesions must not be forgotten.

This is not the place, as it seems to me, to enter more minutely into the numerous details relating to these difficult operative procedures.

(*b*) *In the Chronic Cases.*—The treatment of chronic mastoid disease is fundamentally the same as that for the acute form; its object being, in both conditions, to remove from the mastoid portion of the temporal bone a focus of suppurative disease which is threatening to extend to the sigmoid sinus, or to the brain, or to both. There is one respect, however, in which the operative problem presented by the chronic form of the disease occasionally differs materially from that presented by the acute form. I refer to the fact that in the former it sometimes seems very desirable, if not indeed a necessity, to provide a broad channel through which we may easily reach every part of the antrum and vault of the tympanum from the external auditory canal. The necessity for such a provision may sometimes arise in an acute case of rather long standing; but under ordinary circumstances we are at liberty, in the acute cases, to ignore, in a large measure, the antrum and epitympanic space. The ordinary Schwartze operation meets all the requirements of such cases. In many of the chronic cases, on the other hand, the area of the suppurative disease extends from the epitympanic space back into the antrum,

or into a still larger cavity composed partly of the antrum and partly of the space once occupied by adjoining pneumatic spaces which have become obliterated by ulcerative disease. When we find that we are not able to effect a thorough cleansing of such a cavity—the one thing absolutely essential to a cure of the disease—we are then forced to perform one of three operations: either the usual Schwartze operation, or the operation known as the Stacke operation, or a combination of the two (termed, for convenience, the Schwartze-Stacke operation). Prior to 1890, our only resource, in cases of this kind, was the Schwartze operation. When the work of removing the products of disease and the affected bone structure was done in a thorough fashion, this operation generally gave very satisfactory results. But every now and then a case was encountered in which the relief obtained by the Schwartze operation proved to be only partial in character. It was this experience, doubtless, which led to the search for a method of operating which would leave the antrum and epitympanic vault so completely exposed to view (through a speculum introduced into the outer canal of the ear) that at any time, and as often as might be thought desirable, these regions could be thoroughly cleansed and medicated. It was in this way that *the Stacke operation* came into existence (in 1890). The fundamental idea of this method of operating is to cut away the bony structures which constitute the outer wall of the antrum and of the tympanic vault, and thus to render it possible for the surgeon to see every part of the cavities through a fairly large speculum introduced into the external auditory canal in the usual manner. Whereas in the Schwartze operation all the work upon the bone structures is done from behind, through an opening made in the body of the mastoid process, in the Stacke operation this work is all done through the broad channel of the osseous external auditory canal, after the displacement

forward of all the soft parts which in large measure fill this space.

In the Schwartze-Stacke operation the establishment of an opening into the antrum, in the usual manner, renders—as it is believed—the Stacke part of the operative task both safer and easier to accomplish.

CHAPTER XI.

PATHOLOGICAL ALTERATIONS OF THE MEMBRANA TYMPANI AND THEIR SIGNIFICANCE.

In examinations of the ear one frequently encounters tympanic membranes that present lesions, the significance of which it is important to understand. The lesions to which I have reference are not those which indicate the present existence of some active disease, but rather those which tell the story of some past disturbance. The more important of these alterations will be described briefly in the following paragraphs.

1. Calcareous Deposits.

These are usually seen in the form of white patches which possess sharply defined boundaries. According to Politzer the chalky particles are commonly deposited in the tissues of the substantia propria alone, but at times they may also be found spread out over both of its surfaces—beneath the epidermal layer, on the one hand, and beneath the mucosa, on the other. The polished outer surface of these white patches furnishes sufficient proof of the fact that this foreign material lies between the layers and is not affixed to the outer surface of the membrane. By means of a probe, or, better yet, by aid of the point of a paracentesis needle, one may easily verify the fact that the patch is really a plate of stone-like hardness. When practically the entire drum-membrane is invaded by this pathological change, mere ocular inspection will often have to be supplemented by this test of touching the parts before one can be perfectly sure of the nature of the lesion.

As regards the significance of such patches, it is generally believed that they furnish good evidence that at some time in the past a suppurative inflammation must have occurred in the corresponding tympanic cavity; that, after the subsidence of the inflammation, aggregations of pus cells were left behind in the tissues; and that these, in the course of time, became converted first into cheesy, and then into calcareous material. At post-mortem examinations these calcareous deposits have also been found in the neighborhood of the stapedio-vestibular joint, a location where they could scarcely fail to cause a marked degree of deafness. When, therefore, a calcareous plate is observed in the tympanic membrane of an ear which is seriously deficient in hearing power, we are justified in entertaining the suspicion that a similar deposit of calcareous material has probably taken place in the vicinity of the foot-plate of the stirrup.

FIG. 62.—Horseshoe-shaped Deposit of Calcareous Material in the Membrana Tympani. (After Politzer.)

2. Thickening and Hardening.

These alterations are undoubtedly the result of some previous inflammatory action; but it is not always clear why in one series of cases they should be produced, while in another series we should find atrophy and sclerosis. As a rule, it is true, the thickening and hardening owe their production to some previous suppurative inflammation, whereas the atrophy and scelerosis may generally be traced to the non-suppurative variety.

3. Atrophy.

Atrophy of the membrana tympani is a lesion which may be observed either with or without the condition known as

sclerosis of the mucous membrane of the middle ear. Long-continued atmospheric pressure upon the outer surface of the drum-membrane, when it is not counterbalanced by a pressure of equal power upon its inner surface, causes gradual absorption of the substantia propria to take place. A drum-membrane without any substantia propria is like a piece of thin india-rubber, and may be stretched to an extraordinary degree before a rupture will occur. In extreme cases it may be seen lying like a thin film over the inner wall of the tympanic cavity; and under these circumstances even the most experienced observer may at times be in doubt, for a moment or two, whether he is dealing with a case of this kind, or with one in which the membrana tympani is totally destroyed. After a gentle inflation of the middle ear this delicate elastic membrane will be found blown out far beyond the plane of the normal drum-membane. As it remains only a very short time—not more than a minute or two—in this condition of extreme distention, the physician, after administering the inflation, must at once make the examination with speculum and reflected light.

The lesser degrees of atrophy from pressure are doubtless of frequent occurrence, but they generally escape detection. In cases of sclerosis of the mucous membrane of the middle ear, we find an atrophy of the membrane which seems to differ from that which I have just described. The membrane is apparently just as thin and transparent as in the other form of atrophy, but it seems to retain its substantia propria unchanged; for the membrane is at most very little sunken, and inflation does not cause it to bulge to an unnatural extent. This condition, as it appears to me, may be explained in the following manner: The atrophy is probably limited to the mucous membrane lining the membrana tympani; although perhaps the contraction, which is a fundamental part of the process of sclerosis, may at the

same time interfere with the circulation of blood in this membrane to such an extent as to diminish materially its entire blood-supply, and in this way lessen the bulk of the substantia propria.

4. Abnormal Depression.

Closely allied to this condition of atrophy is that of an abnormally depressed membrana tympani. So far as I am aware, there are only two forces which are competent to effect this, viz., unresisted, or inadequately resisted, atmospheric pressure upon the outer surface of the membrane, and the retraction of any false membranes which may run from the lower end of the manubrium mallei to the inner tympanic wall. It is doubtful whether mere retraction of the tendon of the tensor tympani muscle can do more than increase the tension of the membrana tympani. When the so-called *adhesions*—bands of newly formed connective tissue—pass from the lower end of the manubrium mallei to the inner wall of the tympanum, they may by their retraction produce a marked inward rotation of the malleus. But such adhesions are usually found to be associated with other easily recognizable evidences of a former severe inflammation of the middle ear. On the other hand, when the depression is due simply to increased atmospheric pressure (by reason of an obstructed Eustachian tube), all such evidences of a former suppurative disease will be lacking. The signs which indicate whether a drum-membrane is or is not depressed are the following:—the manubrium mallei will appear to be shortened; its tip will seem to be nearer the posterior and upper than the anterior and inferior boundary of the membrane; the manubrium mallei will form with the posterior fold an acute angle (instead of, approximately, a right angle); the processus brevis of the malleus will stand out more conspicuously than usual; the posterior fold will look like a well-defined horizontal ridge; there

will be a pit-like depression just above the processus brevis (due to the sinking in of the membrana flaccida); and, finally, the bright spot will lose its triangular shape and will appear as a mere dot or as an ill-defined area of light.

5. Cicatrices.

What are called cicatrices or cicatricial spots in the membrana tympani represent tissues which have been reproduced for the purpose of replacing those which have been destroyed. In this sense, therefore, they are identical with the cicatrices observed elsewhere upon the surface of the body, and the use of the term is perfectly justified; but as regards the appearance which they present to the eye of the observer, the two are quite different. The cicatrix of the membrana tympani is simply—so far as its physical characteristics go—a well-defined area of atrophied drum-membrane. There is an entire lack of anything like what is called, in healed wounds of the skin, "cicatricial tissue."

It often happens that a cicatrix, under the influence of increased atmospheric pressure from without (due to an obstructed Eustachian tube), forms a well-marked diverticulum, which projects inward until it comes to rest against the mucous membrane of the promontory. When one examines a drum-membrane in which this condition of the parts exists, the first impression will be that there is an open perforation, leading directly into the tympanic cavity. It is only after the middle ear has been inflated that the true condition of the parts becomes manifest. The sunken cicatrix, under the influence of the inflation, becomes a thin, distended elastic bag upon the outer surface of the drum-membrane. In a very short time, however, it returns to its original resting-place against the promontory.

The amount of substantia propria which is reproduced in these cicatrices seems to vary a good deal. In the smaller

ones enough of this tissue is frequently reproduced to prevent the cicatrix from stretching out into a bag or diverticulum when air is forced into the middle ear by means of a Politzer's bag. In the larger ones, however, newly reproduced substantia propria seems to be almost entirely lacking, and there is a corresponding elasticity of the cicatrix.

So far as size is concerned, this may vary from an area no larger than the head of a pin to one which corresponds to nearly the full dimensions of the membrana tympani.

6. Dilated Surface Blood-Vessels on an Opaque Background.

This picture is one of comparatively rare occurrence. Under normal conditions the membrana tympani possesses two separate networks of blood-vessels: one which is spread out between the mucous membrane and the substantia propria, and a second which is similarly spread out between the latter and the epidermal covering. It is therefore easy to understand that under a sufficiently high pressure from within, the first network of blood-vessels—that which lies next to the mucous membrane—might be completely closed, and the outer network thus be forced to do double duty by way of compensation. In the cases in which I have observed these dilated and tortuous blood-vessels crossing the outer surface of a yellowish-white and thoroughly opaque drum-membrane, the pressure from within was supplied by an accumulation of cheesy material.

7. Alterations in Color.

In certain exceptional cases the membrane may seem to have a deep red or a purplish color, and yet on careful examination it will be found that there is no recognizable fulness of the plexus of blood-vessels running between the epidermis and the substantia propria. In such cases the coloration may be due either to the presence of a blood-

stained serum in the middle ear, or to the reflection of light from an engorged mucous membrane covering the promontory.

Then besides these there are rare instances in which the lower third, or at most the lower half, of the membrane alone presents a distinctly red coloration. One's first impulse, on seeing this picture, is to assume that blood-stained serum fills the middle ear to a corresponding level or depth. However, in the only instances of this phenomenon which I have seen, the upper limit of the colored area did not move in response to the movements of the patient's head, but remained fixed. There was no fluid exudation in the middle ear, but, instead, the floor of this cavity was occupied by a well-characterized vascular new-growth (hæmangioma) which sprang from the mucous membrane.

Finally, the presence of a yellowish serum in a middle ear whose lining mucous membrane is highly congested will give to the membrana tympani, under reflected light, a dark bottle-green color. The entrance of air into the tympanum when thus filled with serum will cause a still further modification of the picture, viz., that due to the presence of sharply outlined bubbles of air.

8. Perforations.

These are among the commonest pathological lesions observed in the membrana tympani. They are usually circular or ovoidal in shape, and it is rare to find more than one in the same drum-membrane. The existence of such a defect in this membrane furnishes unmistakable evidence of the fact that a destructive disease has been at work in the corresponding middle ear, but there is nothing in the appearance, size, shape, or location of the perforation which can surely enlighten us in regard to the nature of the disease which has wrought the damage. In making this statement I exclude those perforations which are of

traumatic origin, and whose irregular shape usually suggests at once the thought that ulcerative disease has had nothing to do with their formation.

If the membrana tympani has been entirely destroyed, the picture presented to the eye will vary according to the amount of damage simultaneously inflicted upon the various structures of the tympanic cavity. In a few instances these will be found in an apparently undamaged condition; and, in this event, the picture presented to the eye will be not unlike that shown in Fig. 63. As a rule, however, all the finer anatomical relations are no longer recognizable in these cases.

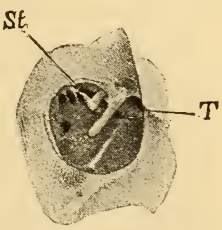

FIG. 63.—Direct View of the Tympanic Cavity after the Removal of the Anterior Wall of the External Auditory Canal and the Tympanic Membrane. (After Zuckerkandl.) *St*, Tendon of the stapedius muscle; *T*, tendon of the tensor tympani muscle, with fold.

9. Adhesions.

As a result of inflammatory action the drum-membrane may become attached, at one or more isolated points, or even throughout a large part of its area, to the opposite inner wall of the tympanum or to the incus or stapes. Under simple inspection it may not be possible to determine the fact that such adhesions exist, but when the membrane is sucked outward by the apparatus known as *Siegle's tympanoscope or pneumatic ear speculum*, the adherent parts will remain unmoved, while those which are free will come forward under the influence of the suction. Through the glass diaphragm, which is set in the mouth of the speculum at an angle which does not permit

FIG. 64—Cicatricial Retractions and Band-like Thickenings in the Membrana Tympani, which is adherent to the inner wall of the tympanum. (After Politzer.)

the formation of an image by reflection, one may watch the behavior of the drum-membrane under these varying conditions, and in this way readily detect the exact points at which such adhesions exist.

10. Habitual Distention.

Habitual distention of the tympanic membrane in an outward direction is an abnormal condition which is occasionally encountered. Its significance is this: it indicates that air finds its way quite readily from the vault of the pharynx through the Eustachian tube into the middle ear, but that in some way the escape of this air back into the pharynx is hindered. The result of this condition of affairs is that an excess of air is habitually imprisoned in the middle ear, and that consequently the membrana tympani is in a state of distention a large part of the time. The picture presented to the eye of the observer is that shown in Fig. 42.

11. Miscellaneous Conditions.

Still other lesions, in addition to those enumerated above, are sometimes observed in the tympanic membrane. Well-defined *vascular new-growths* are of very rare occurrence. So too are *horny growths*, like the one reported by Dr. B. Alexander Randall, of Philadelphia, and pictured in my larger treatise (Fig. 30). The complete *absence of the malleus* from an otherwise perfect membrana tympani may always safely be attributed to the fact that it has previously been removed by surgical means. Finally, there are two cases on record in which a *hook-shaped manubrium mallei* was observed.

In rare cases the membrana tympani may be the seat of the lesions of tuberculosis and syphilis.

CHAPTER XII.

SKETCH OF THE ANATOMICAL RELATIONS AND PHYSIOLOGY OF THE NERVOUS APPARATUS OF HEARING.

1. Anatomy of the Labyrinth.

If we take a human temporal bone, either in its natural fresh conditon or in the dried state, and endeavor by simple inspection to get some idea of the form, size, and relations of the labyrinth, we shall fail completely. There are only three points—the oval window, the round window, and the meatus auditorius internus—where we can get a glimpse of the approaches to this system of cavities. At all other points the various channels and cavities of the labyrinth are deeply imbedded in the substance of the petrous portion of the temporal bone. It is only by aid of a hammer, chisel, and knife that we can obtain the thin shell of bone which represents, as it were, the mould of the contained cavities. (See Figs. 65 and 66.) In this way we shall find that the labyrinth—

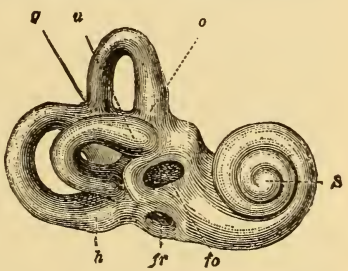

FIG. 65.—Thin Shell of Bone Immediately Surrounding the Vestibule, Cochlea, and Semicircular Canals, and Showing the Form and Relations of these Cavities to Each Other. (Right ear.) (After Gruber.) *o*, Upper semicircular canal; *h*, posterior semicircular canal; *g*, terminal canal common to both the posterior semicircular canals; *fo*, foramen ovale; *fr*, foramen rotundum; *S*, cochlea.

FIG. 66.—The Right Osseous Labyrinth of a New-born Infant, Opened on its Posterior Surface, Magnified about Four and a Half Diameters.

1. The fenestra cochleæ partially opened. The curved projection about 5 mm. distant from the lower edge of the fenestra rotunda (measured on the picture), appears to be the commencement of the outer wall of the cochlea, and the ridge opposite the lamina spiralis ossea represents a prolongation of the lamina spiralis accessoria, to which the lamina spiralis membranacea is attached, as far as the interior of the vestibule. The bony bridge across the commencement of the spiral canal was retained in the preparation because of the attachment of the vestibular end of the osseous spiral lamina to that portion of the wall.
2. The osseous spiral lamina (lamina spiralis ossea) projects 1.5 mm. from the inner wall of the cochlea. At the point of its origin from the wall of the cochlea, it is at first irregular; that is to say, there is a succession of uniform depressions, separated from each other on the under surface of the spiral lamina by small bony ridges, which gradually disappear toward its free edge.
3. The osseous spiral canal of the cochlea (canalis spiralis cochleæ) is divided by the spiral lamina into two passages or scalæ. The lower and broader is called the tympanic, and the upper and narrower the vestibular passage —scala tympani, scala vestibuli.
4. The floor of the internal meatus, with the openings of the commencement of the Fallopian canal and the four depressions of varying size which receive through the five perforations (foramina cribrosa) the fibres of the nervus acusticus, and the vessels accompanying it into the labyrinth. The three smaller depressions are the maculæ cribrosæ internæ, which receive the vestibular nerves, and the larger spiral-shaped depression marks the base of the cochlea. (In the photograph, unfortunately, the

we are speaking now only of its osseous boundaries—consists of a central cavity, from four to six millimetres in diameter, from one side of which spring, like arches, the three semicircular canals, while from the other side a canal leads into the snail-shaped body called the cochlea. In their natural state these bony cavities are filled with membranous structures and fluid. Thus, for example, the central cavity, the *vestibule*, contains two distinct membranous sacs which together do not quite fill the entire space of the cavity, but leave room, in the immediate vicinity of the foot-plate of the stapes, for a certain amount of free fluid—*the perilymph*. The smaller of the two sacs, the *saccule* (*S*, in Fig. 67), communicates with one of the membranous channels of the cochlea, the *ductus cochleæ* (*D.c.*, in Fig. 67). The larger sac, the *utricle* (*U*, in Fig. 67), is continuous with the membranous tubes which partially fill the osseous semicircular canals. The two sacs just mentioned do not communicate with each other directly. From each, however, a narrow membranous duct is given off, and these two unite together, at a short distance from the parent sacs, to form the so-called

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spirally arranged openings [tractus spiralis foraminulentus] lie in deep shadow.)

5. The vestibule (vestibulum osseum) has a height of 6.1 mm., and a breadth of 4.7 mm. In the tympanic wall, thrown somewhat into shadow in the photograph, is the fenestra ovalis, and toward the right, the openings which lead into the semicircular canals.
6. The posterior semicircular canal opened from behind, arising by its inferior osseous ampulla, curves upward, and joins the superior or sagittal canal in the common termination which opens into the posterior wall of the vestibule.
7. The superior semicircular canal, opened from behind and above, arises by the superior ampulla from the upper wall of the vestibule, near the figure 5, and curves upward and backward to unite with—
8. The posterior semicircular canal in the common termination.
9. The horizontal semicircular canal, much foreshortened in the plate, arises near the common termination of the two other canals, and re-enters the vestibule below and near the same, with an expansion of its end, which has sometimes the form of an ampulla.

(Copied from the Rüdinger Atlas of the Osseous Anatomy of the Human Ear; translated by Dr. Clarence J. Blake. Boston: A. Williams & Co., 1874.)

aquæductus vestibuli (*A.v.*, Fig. 67), or *ductus endolymphaticus*, which traverses the intervening bone and communicates with the endolymph of the cranial cavity. An-

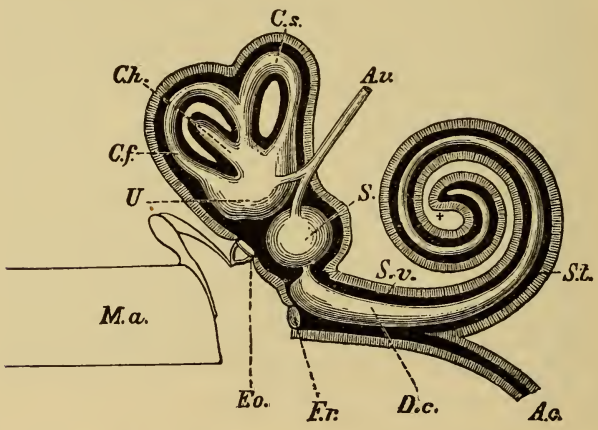

Fig. 67.—Diagram Showing the Relations of the Membranous Structures of the Labyrinth to One Another, to the Surrounding Bony Walls, and to the Transmitting Apparatus of the Middle Ear. (After Arthur Hartmann.) *Ma*, External auditory canal; *U*, utriculus; *Cf*, frontal semicircular canal; *Ch*, horizontal semicircular canal; *Cs*, sagittal semicircular canal; *Av*, aquæductus vestibuli; *S*, sacculus; *Sv*, scala vestibuli; *St*, scala tympani; *Ac*, aquæductus cochleæ; *Dc*, ductus cochleæ; *Fr*, fenestra rotunda; *Fo*, fenestra ovalis.

other small membranous channel, the *canilis reuniens of Hensen*, establishes a direct communication between the saccule and the ductus cochleæ (*D.c.*, Fig. 67). The mass of fluid (the perilymph) surrounding the saccule and utricle is a direct continuation of that which fills the upper spiral staircase of the cochlea, the *scala vestibuli* (*S.v.*, Fig. 67), and also—through a small opening at the very top of the cochleal whorl, called the *helicotrema* (see Fig. 68)—of that which fills the lower spiral staircase, the *scala tympani* (*S.t.*, Fig. 67). A spiral diaphragm, which is exceedingly complex in structure, contains within it a small

duct filled with fluid—the endolymph—and called the *ductus cochleæ* (*D.c.*, Fig. 67).

These coarser relations of the different cavities, ducts, and masses of fluid contained within the labyrinth may all be made out either with the naked eye or by aid of lenses of feeble magnifying power, and they are well shown in Hartmann's diagram (Fig. 67).

As regards the finer details of the labyrinthine structures, I shall make no attempt to give here more than a very superficial description. The *membranous semicircular canals*, to begin with, present but few peculiarities worthy

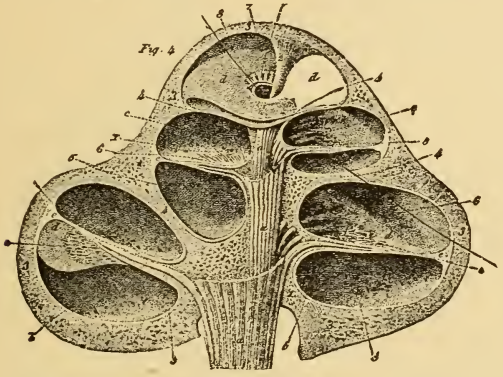

Fig. 68.—Transverse Section of the Human Cochlea in the Plane of the Axis of the Modiolus. (After Breschet.) × circa 12 diameters. *a*, *a*, *a*, Trunk of the cochlear portion of the auditory nerve; *b* *b*, filaments of this nerve branching off from the trunk and passing into the substance of the lamina spiralis ossea; *c*, *c*, anastomosing nerve filaments; *d*, *d*, lamina spiralis membranacea; *e*, *e*, ligamentum spirale of Henle; 1, 1, 1, osseous modiolus; 2, columella; 3, 3, outer bony shell of the cochlea; 4, 4, partition of bone separating the individual cochleal whorls; 5, 5, tympanic portion of the lamina spiralis ossea; 6, 6, vestibular portion of the same; 7, hamulus; 8, helicotrema. A black bristle is represented as passing from the scala tympani below, through the helicotrema, into the scala vestibuli above.

of note. A cross section of one of them reveals the fact (easily observable in ordinary dissections) that it fills but a small portion, perhaps one-third, of the calibre of the osseous

semicircular canal. The inner surface of this membranous canal is lined with columnar epithelium, and this epithelial lining, when not distended by endolymph, is thrown into folds or rugæ. Like every other part of the labyrinth the semicircular canals are well supplied with blood-vessels; but nerve filaments have not been discovered in any part of these canals except in the ampullæ.

The *utricle* and *saccule* present no anatomical features of special interest. The saccule is round in form and communicates with the ductus cochleæ through the medium of the canalis reuniens of Hensen. Both in the saccule and in the utricle there is one spot where the wall of the sac is thickened, partly by an increase in the amount of the connective tissue, but also in large measure by reason of the presence of an aggregation of peculiar cylindrical epithelial cells which stand in direct communication with nerve fibres coming from the ramus vestibuli of the auditory nerve. These spots are called the *maculæ acusticæ*. The free extremities of these epithelial cells are provided with hair-like cilia or rods, and among them are scattered (post-mortem at least, if not during life) the small six-sided crystals of carbonate of lime known as *otoliths*.

There still remains to be considered the *cochlea*, the most complicated and evidently the most essential part of the labyrinth. The auditory nerve, it will be remembered, gains entrance into the cochlea by way of the *modiolus*—the cone-shaped standard of bone around which the cochleal channels are coiled spirally. The base of this standard corresponds with the cribriform bottom, or *cul-de-sac*, of the porus acusticus internus; its summit, with the cupola or highest point of the scala vestibuli. The modiolus is traversed lengthwise by countless channels through which run the filaments of the auditory nerve. From the base to the vicinity of the summit of this conical core of the cochlea, nerve filaments are constantly being given off laterally to the

spiral diaphragm which separates the two scalæ from each other. Just as the filaments are about to leave the modiolus and enter the substance of the *lamina spiralis*,—the

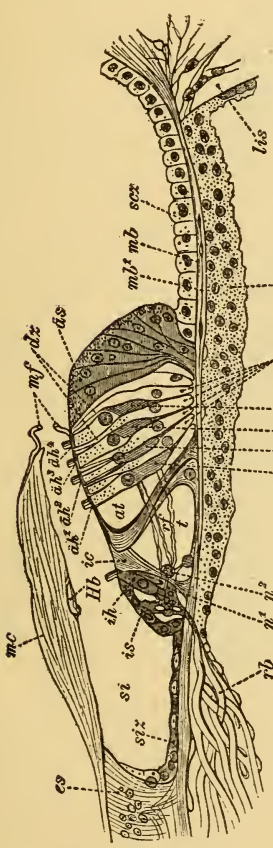

FIG. 69.—Radial Vertical Section of the Papilla Acustica Basilaris or Corti's Organ, from the Middle Whorl of the Cochlea of a Man 29 Years of Age. (After Retzius.) *es*, Limbus laminæ spiralis; *mc*, membrana tectoria or membrane of Corti; *Hb*, Hensen's band; *mf*, fibres which attach the membrane of Corti to the basilar membrane; *si*, sulcus spiralis internus; *siz*, epithelium of the sulcus spiralis internus; *is*, inner epithelial or supporting cells; *ic*, inner pillars, the heads of which articulate with those of the outer pillars; *i*, the tunnel-shaped space under the arch formed by the junction of the inner and outer pillars; *ih*, inner hair or ciliated cells; *äh*¹, *äh*², *äh*³, *äh*⁴, four rows of outer hair or ciliated cells; *dz*, Deiters cells, intercalated between the outer hair cells; *äs*, Hensen's supporting cells; *rb*, nerve fibres of the Ramulus basilaris; n^1, n^2....n^6, outer twigs of the spiral nerve fibres; *rf*, radial nerve twigs which cross the tunnel-like space; *at*, inner portion of Nuel's space; *mb*, upper layer of the membrana basilaris; *mb*¹, lower layer of the membrana basilaris; *tb*, tympanal coating of the membrana basilaris; *lis*, ligamentum spirale.

technical name of the diaphragm just mentioned,—they pass through an aggregation of ganglion nerve cells (ganglion spirale). Up to this point, and even beyond it, as far

as to the line of junction between the lamina spiralis ossea and the lamina spiralis membranacea, the nerve filaments retain their sheathing (white substance of Schwann, etc.), but after they pass this last point they are encountered only as delicate nerve fibrillæ, like those which are found in the rabbit's cornea.

The spiral diaphragm separating the scala tympani below from the scala vestibuli above is found, on more careful examination, to contain within itself a third channel—

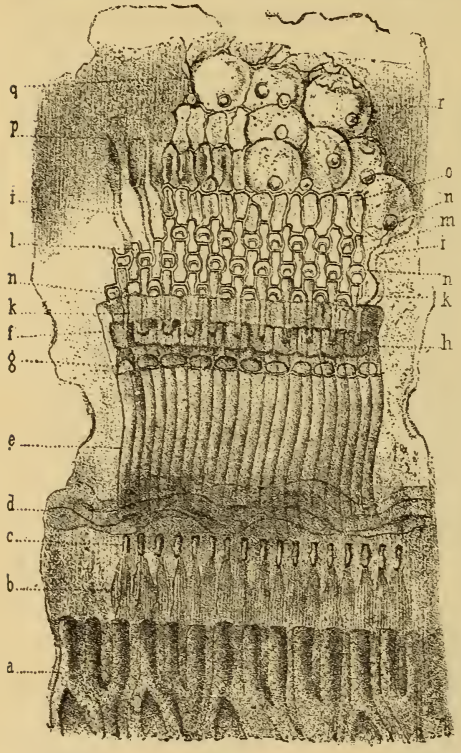

FIG. 70.—Surface View of the Organ of Corti and the Entire Lamina Velamentosa (= lamina reticularis). (After Deiters.) *a*, Huschke's hearing teeth (Corti's first row of teeth); *b*, bundles of dark-bordered nerve fibres; *c*, openings of the habenula perforata; *d*, vas spirale; *e*, first row of Corti's fibres (= inner pillars); *f*, pars membranosa of the lamina reticularis; *g*, line of union of the first and second rows of Corti's fibres (*i.e.*, of the inner and outer pillars); *h*, the second row of intermediate connecting pieces; *i*, second row of Corti's fibres; *k*, rods; *l*, first row of phalanges; *m*, second row of phalanges; *n*, *n*, *n*, the three rows of circles with their inner arches; *o*, the first row of rectangular frames; *p*, two additional rows of rectangular frames (these are sometimes lacking); *q*, connective-tissue framework supporting the large cells (*r*).

the scala or ductus cochleæ—the fluid contents of which bathe the complicated structures known collectively as Corti's organ. It is here that the delicate fibrillæ of the auditory nerve may be traced to their ultimate destination, and it is here, beyond all question, that those sensations are elaborated which reach the brain as impressions of sound.

The more important individual histological elements entering into the formation of Corti's organ are the following:

1. The *lamina spiralis membranacea*, or the *membrana basilaris*.—This membrane, which is attached along its inner border to the outer edge of the lamina spiralis ossea, and is inserted into that part of the outer wall of the cochlea which is known as the *ligamentum spirale* (Fig. 68, *e*), is subdivisible into three zones, viz., the inner, the middle, and the outer zones. The inner zone is extensively perforated, to permit the passage through it of nerve filaments from the auditory nerve; hence its name, *zona perforata*. The middle zone is that part of the membrana basilaris which affords immediate support to the organ of Corti; it is called the *zona arcuata*. The outer zone is finely striated in a direction at right angles to the long axis of the membrane; that is, as if the striæ radiated from the central axis of the modiolus.

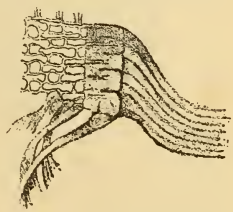

FIG. 71. — Detached Fragment of Corti's Organ, showing the upper parts of the inner and outer pillars, and a portion of the lamina velamentosa or reticularis. At one part of the latter the cilia of the hearing cells still remain attached. (After Deiters.)

2. A series of stiff but elastic rod-like bodies which occur in two rows and are so disposed as to form an arched way above the membrana basilaris. These are the *outer* and *inner pillars of Corti* (also known as *Corti's fibres* or *rods*).

In their anatomical relations these pillars present one or

two peculiarities which throw some light upon their physiological function: their bases are firmly anchored to the membrana basilaris, while their upper ends or heads articulate one with another—each inner pillar with its corresponding opposite outer pillar—in such a manner as to suggest for these parts the very sort of vibratory motion (in an up-and-down direction) which on theoretical grounds has been attributed to them.

3. A peculiar fenestrated membrane, the *lamina reticularis*, which extends in a horizontal direction some little distance outward from the heads of the pillars of Corti, to which it seems to be in some way attached.

4. Five rows of ciliated cells, four on the outer side of the arch, and one on the inner side, close to the inner pillars of Corti. The four outer rows insert their heads into the openings of the fenestrated lamina reticularis in such a manner that the cilia stand up like fine but short rods at regular intervals along the surface of the membrane. Bundles of primitive nerve-fibrils from the cochleal branch of the auditory nerve have been traced to all five rows of ciliated cells, but to no other structures in the ductus cochleæ. Hence the name of *hearing cells* which has very appropriately been awarded to these evidently the most important elements in the apparatus we are endeavoring to describe.

5. Simple epithelial cells, destined apparently to serve as a support to the lamina reticularis and to the outer and inner rows of hearing cells.

6. A peculiar membranous structure, which starts from the upper side of the hooked-shaped process of the *lamina spiralis* and extends outward over the lamina reticularis. This membrane is mucoid (or doughy) in consistency, and, from the fact that it lies like a gelatinous veil over, and perhaps in contact with, the cilia of the hearing cells, it is called the *membrana tectoria* or covering membrane—also

Corti's membrane. As far as to the outer limit of the hearing cells, this membrane retains its thick, doughy consistency. From the appearance of the parts it is believed that

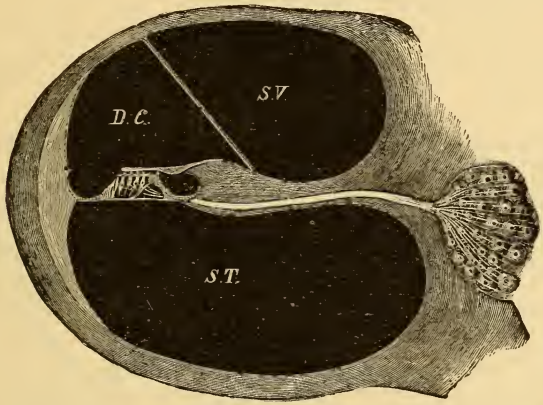

FIG. 72.—Transverse Section of a Cochleal Whorl (diagrammatic). On the right, embedded in the substance of the bone, is a group of ganglion cells, through which the fibres of the auditory nerve pass before entering the lamina spiralis ossea. This latter is represented in the figure as a broad septum separating the scala vestibuli (*S. V.*) from the scala tympani (*S. T.*), and containing a canal for the passage of the auditory nerve filaments. The latter, on emerging from the lamina spiralis ossea, pass in part directly to the inner row of hearing cells, and in part beneath the arch of Corti's pillars to the four outer rows of hearing cells. The cilia belonging to the latter may be seen projecting through the lamina reticularis; those of the single row of inner hearing cells project above the head of the inner pillar of Corti. The lamina reticularis is drawn as a horizontal projection (outward) of the upper portion of the head of the outer pillar of Corti. Above, the cilia of the hearing cells are covered by the membrana tectoria or Corti's membrane, which springs from the outer hook-shaped edge of the lamina spiralis ossea and terminates at a point in the immediate vicinity of the outermost row of hearing cells. The space bounded below by the organ of Corti (membrana basilaris and superimposed structure) and above by Reissner's membrane (represented in the drawing by a straight band which extends from the bony wall of the cochlea downward and inward to the upper side of the lamina spiralis ossea), is called the ductus cochleæ (*D.C.*).

in its natural state the membrana tectoria does not terminate in a free border, but is attached to the underlying cellular structures at some point beyond the limit of the

outermost row of hearing cells. By several authorities it is maintained that fibrils pass from the under surface of the membrana tectoria to the upper extremity of each hearing cell belonging to the four outer rows.

7. A thin, membranous diaphragm, separating the scala cochleæ from the scala vestibuli, and known as *Reissner's Membrane.*

2. Mechanism of the Labyrinthine Structures in the Act of Hearing.

It is a difficult task to build up a theory which shall explain satisfactorily what takes place, in the act of hearing, in all these different labyrinthine structures. Helmholtz's theory, which makes this act to depend upon the sympathetic vibration of the organs of Corti, and attributes to Corti's membrane (Pritchard's membrana tectoria) the function of a damper upon such vibrations, is undoubtedly the correct one, so far as it goes; but it does not go far enough to satisfy one's hunger for knowledge in regard to this question. Unfortunately, the problem is of such a character that we can scarcely hope for such a thing as precise knowledge in regard to its solution, but must rest satisfied with hypotheses which are at most mere amplifications of the Helmholtz theory and of those put forward by Hensen and by Boettcher. There are, however, a number of important points in regard to which the best authorities are agreed.

Thus, for example, I believe that very few will dispute the statement that the impulses of sound reach the cochlea by way of the fenestra ovalis; that the foot-plate of the stapes, after the fashion of a piston, imparts individual shocks to the perilymph which fills a large part of the vestibule and the channel which is called the scala vestibuli; that these shocks, being given to an incompressible mass of fluid, are transmitted without appreciable loss to

Reissner's membrane throughout its entire length—or, in other words, to the endolymph contained within that three-sided tube called the ductus cochleæ; that from the membranous part of the under surface of this tube—*i.e.*, from

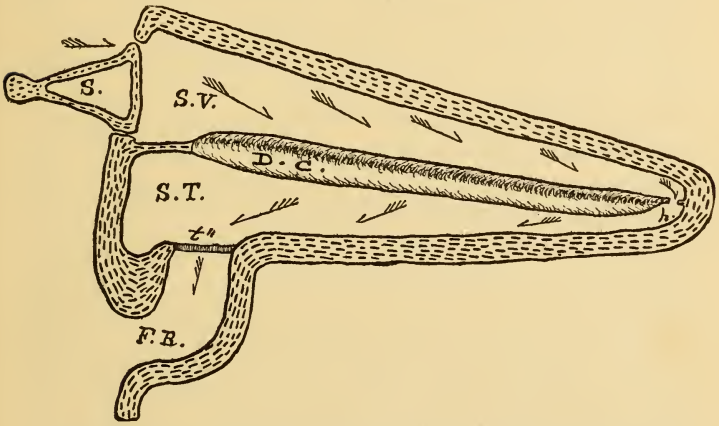

FIG. 73.—Diagram Showing the Mechanical Effects of an Inward Excursion of the Foot-plate of the Stapes upon the Different Structures and Bodies of Fluid Contained in the Cochlea.

When the foot-plate of the stapes (*S*) presses upon the perilymph contained in the scala vestibuli (*S.V.*) it causes the latter to push the entire elongated sac, called the ductus cochleæ (*D.C.*), down toward the scala tympani (*S.T.*). This downward pressure on the part of the cochleal duct in turn causes a corresponding displacement of the perilymph contained in the scala tympani, the ultimate result of which is to force the secondary tympanic membrane (*t''*) in the fenestra rotunda outward toward the tympanic cavity. In this disturbance of the various intralabyrinthine masses of fluid an insignificantly small amount of perilymph doubtless passes from the scala vestibuli through the helicotrema (*h*) into the scala tympani; this amount being unquestionably too small to materially diminish the breadth of the excursion made by the sac composing the cochleal duct (and containing the long keyboard of organs of Corti) in a direction at right angles to its long axis.

the lamina spiralis membranacea—these shocks are in turn transmitted to the perilymph which fills the scala tympani; and, finally, that each individual displacement of this last-named mass of fluid (corresponding to each individual shock or outward phase of a vibratory excursion) finds the amount

of space required for such displacement at the tympanic end of the scala tympani, at which point the secondary tympanic membrane is pushed outward by the perilymph to just the extent which may be necessary for providing this required amount of space. Doubtless the elasticity of all the parts displaced by this excursion inward of the foot-plate of the stapes furnishes all the force required for their return to a condition of rest or equilibrium. Furthermore, few will to-day dispute the necessity of some such contrivance as the helicotrema—the narrow passage of communication, in the cupola, between the scala tympani and the scala vestibuli—for the preservation of the required equilibrium between the pressure exerted from above (scala vestibuli) and that exerted from below (scala tympani) upon the ductus cochleæ, and also, at the same time, for the maintenance of a uniform specific gravity between these two large bodies of perilymph. On the other hand, this channel of communication is so narrow that, with each impulse communicated by the stapes, little or no longitudinal displacement of the perilymph—that is, little or no current in a direction parallel with the ductus cochleæ—can take place. In other words, the stapedial impulses will be felt, along the entire length of the ductus cochleæ, as a force acting chiefly at right angles to its long axis. If we study the relations of the component parts of Corti's organ—that complicated and most delicate piece of machinery which rests upon, and makes a part of, the floor of the cochleal duct—we shall find that they are of such a nature that vibration cannot take place in them except in one direction, viz., up and down, or in a plane which cuts the long axis of the duct at a right angle. Thus, for example, the membranous lamina spiralis—or the membrana basilaris, as it is also called—is not a homogeneous membrane like the membrana tympani, but is composed of separate narrow bands or fibres, which run at right angles to the long axis of the

duct, are placed side by side like the individual keys of a piano, and are feebly glued together, edge to edge, by an interfibrillar gluing material. These, therefore, can only vibrate in planes which cut the duct at a right angle. Then again, the cilia of the hearing cells do not project free into the endolymph, but are, as it were, blanketed by the dough-like membrane of Corti. All lateral motion on their part, therefore, is entirely out of the question. The hearing cells themselves stand in a nearly upright position upon the membranous lamina spiralis, and they are arranged in such a manner that to each band-like or cord-like subdivision of the lamina spiralis a row of four hearing cells is assigned—one upon the inner side of the arch and three upon the outer side. From the summit of the arch a lattice-like framework projects, and into each opening in this comparatively rigid framework the upper end or neck of a hearing cell fits. The arch itself is formed by the junction of two inclined pillars, whose bases are firmly amalgamated with the lamina spiralis; each separate band of the lamina being provided with its own individual arch. All these anatomical arrangements, as it seems to me, utterly forbid the idea of anything like vibration from side to side, as suggested by Boettcher. On the other hand, the mode of union between the head of the inner and that of the outer pillar is of such a nature as to favor strongly the idea of an up-and-down vibration of the organs of Corti. This mode of union suggests that of the two halves of an ordinary hinge; and this hinge-like union is so arranged, in the case of the inner and outer pillars of a Corti's organ, that the only play possible is that which would result from an up-and-down vibration of the whole complex structure. All the anatomical features of the cochleal apparatus seem, therefore, to be in perfect harmony with the hypothesis of vertical vibrations, and with these alone.

But even if this point be conceded, there still remain

other equally difficult problems which demand a solution. One of these, for instance, relates to the *modus operandi* of the membrane of Corti, another to the application of the principle of sympathetic vibration to separate portions of the lamina spiralis with their superimposed structures, a third to the way in which the ultimate fibrillæ of the cochlear portion of the auditory nerve are stimulated by sonorous vibrations, and so on. The parts to which these problems relate are so closely connected that it is scarcely possible to discuss their mode of action separately. I shall therefore restrict my further remarks upon the mechanism of the cochleal apparatus to a consideration of the action of these different parts in combination.

If we reduce the problem of hearing—that is, of the perception of sound—to its simplest form, the question presents itself in these terms: What influence does a simple fundamental musical tone, shorn of all its overtones, exert upon the cochleal apparatus, and how is a special sensation, corresponding to that particular tone, conveyed to the brain? Let us assume that a musical tone of about one hundred vibrations (G^{w}, for example) is produced in the neighborhood of a normal ear. The stapes receives these one hundred shocks and transmits them to the perilymph in the scala vestibuli. In correspondence with these shocks the ductus cochleæ is displaced throughout its entire length, from the vestibule to the cupola, one hundred times; this excursion taking place in the direction of the scala tympani and causing a compensatory displacement of the perilymph contained in that channel. Every one, therefore, of the thirteen thousand or fourteen thousand individual strings[1] of the spirally disposed collection of Corti's organs must, in response to these shocks, likewise perform these one hundred up-and-down excursions. The dough-

[1] Variously estimated by different authorities. Hensen's latest estimate (1871) places them at 13,400.

like but yet elastic membrane of Corti, resting as it does upon the cilia of the countless hearing cells belonging to this long array of Corti's organs, must also necessarily be subjected to this same up-and-down excursion, in precisely the same manner as it would be if it formed an integral part of these organs and were not merely spread out over them like a blanket.

Inasmuch as a slender nerve fibril is supplied to every one of the hearing cells, and to no other structures in the complicated mechanism called Corti's organ, we are justified in drawing the inference that it is upon these hearing cells that the peculiar influence is brought to bear which causes an excitation of the attached nerve fibril, or, in other words, which causes a sensation of sound to be transmitted to the brain. The question, therefore, which requires next to be considered is that relating to the nature of this particular influence. If we examine the structure and relations of the hearing cells, we find that they possess the following characteristics: first, the long axis of each cell invariably runs at nearly a right angle to the plane of Corti's membrane or to that of the membrana basilaris; second, its upper extremity is provided with rod-like cilia of a rather rigid character, unlike those which are seen in other parts of the body and which habitually move in a horizontal direction (that is, a direction at right angles to the long axis of the cell); third, these rod-like cilia furnish a direct support to the overlying membrane of Corti; and, fourth, the lower extremity of each cell is firmly attached to one of the numerous fibres or cord-like subdivisions of the membrana basilaris. These last structures are evidently the only distinctively vibratory elements in the complex mechanism of the cochlea. They alone, of all the cochleal structures, manifest evidences of adaptation to the function of spontaneous vibration, or of vibration at certain fixed rates of speed. They are tensely stretched, and their

length at the cupola is several times (twelve times, as estimated by Hensen) as great as it is at the vestibule. These differences in length certainly favor the idea that the individual units of this series of stretched strings are tuned to vibrate in sympathy with all the known tones of the musical scale; those answering to the deepest tones being located near the cupola, while those which are tuned to the highest pitch occupy the vestibular end of the basilar membrane. Accustomed as we are to think that a deep tone can only be produced by a cord of considerable length, it is indeed a difficult matter to believe that a tense fibre that measures only three or four millimetres in length can by any possibility be brought to vibrate in sympathy with the deeper tones of the musical scale; or indeed, for that matter, to vibrate in sympathy with even the higher ones. We are forced, in the presence of this difficulty, to assume that the principle of the loaded string furnishes the true explanation of how such sympathetic vibration may take place.

After these brief explanatory remarks we may return to the consideration of the question of what constitutes a specific stimulus of an auditory nerve fibril. Hensen's belief is, that a blow upon the terminal ends of the cilia of a hearing cell furnishes this stimulus. The way in which such a blow or series of blows is brought about is the following:

A musical tone of say one hundred vibrations to the second is produced, and in consequence the entire membrana basilaris, with all its superimposed structures, will vibrate at precisely the same rate in an up-and-down direction. Almost everywhere throughout this long stretch of membrane these vibrations are merely passive in character; that is, they occur in response to a series of pushes from above downward which recur at the rate of one hundred in every second. The membrane of Corti, wherever this

passive kind of vibration is going on, remains in contact with the cilia which support it, and follows their up-and-down excursions as if it were glued to their extremities. But there is one part of this long, spiral membrana basilaris where the individual fibres which compose it perform these up-and-down vibrations in a much more vigorous fashion. This they do by reason of the fact that they are tuned so as to vibrate in sympathy with a tone of one hundred vibrations per second; and, as a result of this extra-vigorous vibration, the dough-like membrane of Corti not being attached to the hearing cells, but simply resting by its own dead weight upon their projecting cilia, is no longer capable of following these excursions throughout their full amplitude. In other words, in each one of these excursions there is an instant of time when the membrane of Corti is lifted off the ends of the cilia; and consequently the return of this membrane to its previous position of contact must be accompanied by a tap or blow upon the free ends of these structures. This is the way, as it seems reasonable to suppose, in which the hearing cells are stimulated to send impressions of sound to the brain.

Something similar to this momentary throwing-off of Corti's membrane may be observed in the familiar experiment of placing little riders of paper upon a stretched violin string. Those which are placed at the chief nodal-points are so little disturbed by the vibrations that they generally do not fall off, whereas those which are placed astride the string at other points are usually thrown violently from it as soon as the bow is brought into play. What takes place at the nodal-points of a vibrating violin string may therefore serve to illustrate the relations which probably exist in all those organs of Corti which are undergoing simple passive vibrations. On the other hand, the violent dismounting of the paper riders at other parts of the vibrating string furnishes an exact analogue of what I believe must

take place in the case of those comparatively few fibres which are undergoing sympathetic vibrations. Let us assume, for the sake of illustrating this point more fully, that sixteen separate cords or bands of the membrana basilaris belong to each half-tone of the musical scale.[1] In Fig. 74

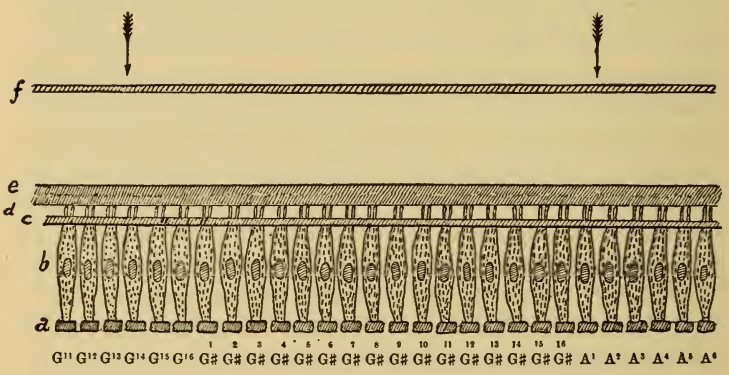

FIG. 74.—Diagram Representing a Longitudinal Section of the Ductus Cochleæ and Including Only its More Important Structures. *f*, Reissner's membrane; *e*, membrane of Corti, or the membrana tectoria; *d*, rod-like cilia of the hearing cells; *c*, membrana reticularis, or membrana velamentosa; *b*, hearing cells, the only cochleal structures which have any connections with nerve fibres; *a*, individual bands or cords (seen in cross section) of the membrana basilaris. For the sake of greater clearness the glue-like material which binds these cords together into a continuous membrane has been omitted in the diagram. The arrows indicate the direction in which motion takes place during an inward excursion of the stapes. (For further details see the main text.)

a series of twenty-eight of these bands is represented. The first six may be assigned to the last part of the series belonging to the tone G natural; then, next to these, come all the sixteen belonging to the tone G sharp; while at the end of the series are placed the first six cords of the tone A natural. During the intonation, upon some musical instrument, of the tone G sharp, sympathetic vibration will occur

[1] As a matter of fact, there must be over thirty of them for each half-tone.

in those bands which are designated in the figure as $G^{1}\sharp$, $G^{2}\sharp$, etc., while those which are marked G^{11}, G^{12}, etc., and A^{1}, A^{2}, etc., will be subjected to simple passive vibrations. These different kinds of vibratory movement are represented graphically in Fig. 75.

There is still another point which must not be forgotten. I refer to the fact that the number of individual organs of Corti is so large that we may safely assign at least thirty or forty of them to each half-tone in the ordinary musical scale. This means that the production of a single simple musical tone never excites to sympathetic vibration a single organ of Corti, or even three or four of them, but always a group of at least thirty or forty consecutive fibres or organs. Those occupying the centre of such a group ($G^{7}\sharp$, $G^{8}\sharp$, and $G^{9}\sharp$, for example, in Fig. 74) will vibrate most vigorously, for they are always the ones which are most perfectly tuned, while those situated at the two extremes ($G^{1}\sharp$ and $G^{16}\sharp$) will be the least agitated, inasmuch as their tuning is the most imperfect. The mechanical result of this state of affairs must be a wave-like disturbance of a limited area of the membranous lamina spiralis.

G *G♯* *A*

Fig. 75.—Diagram Showing the Difference between Sympathetic and Passive Vibrations. At *G* and *A* the vibrations are passive in character, while at *G♯* they are extra vigorous, by reason of the fact that the cords which produce them are tuned to precisely the same pitch as that of the tone which excites them to vibration.

The time has not yet arrived when we may, with any degree of confidence, formulate a theory as to what is the mechanism of the structures located in the semicircular canals. Suffice it to say, therefore, that the consensus of opinion favors the view that the organ of equilibrial sense resides in this part of the labyrinth, and that its more important structures are located in the parts which are known as the ampullæ (Fig. 66, 6 and 7).

CHAPTER XIII.

DISEASES IN WHICH THE NERVE OF HEARING IS BELIEVED TO BE INVOLVED.

1. Pathology.

Notwithstanding all the efforts which have been made by otologists during the last three decades to furnish methods of diagnosis whereby we may distinguish, with some degree of accuracy, between the different functional and organic diseases of the auditory nerve, we are to-day still unprovided with these means, and are therefore obliged, while waiting for more precise knowledge, to speak in a reserved and uncertain manner about the different pathological alterations which, as we believe, may affect this nerve or the parts adjacent to it.

Thanks to the painstaking investigations of Moos and other German physicians, it is now a demonstrated fact that in measles, scarlet fever, and diphtheria—and possibly in other diseases—the invasion of the middle ear by the streptococcus and other varieties of destructive micro-organisms may be followed by a similar invasion of the cavities of the labyrinth. When, therefore, in the course of any of the diseases named, the suppurative inflammation of the middle ear terminates in the complete annihilation of the hearing of the affected ear, we are perfectly warranted in ascribing this loss of function to the destructive action of bacteria which have wandered from the tympanum into the whorls of the cochlea. I am not aware that the same demonstration has, up to the present time, been furnished for

the disease known as epidemic cerebro-spinal meningitis; and yet there can be no reasonable doubt that the total loss of hearing, which is so common an event in this disease, is also to be ascribed to an invasion of the labyrinth by bacteria. But this latter invasion differs considerably, both in character and in results, from that which occurs in the course of scarlet fever. Whereas in the latter disease the microbes enter the labyrinth from the tympanum by way (probably) of the secondary tympanic membrane and the cochlea, and in the main confine their action to a destruction of the nervous apparatus of hearing, in epidemic cerebro-spinal meningitis they enter this cavity from the direction of the brain; their actual pathways being, in all probability, the aquæductus vestibuli and the aquæductus cochleæ. Along these routes the bacteria would find easy access both to the ampullæ of the semicircular canals and to the scalæ of the cochlea; and consequently we should expect from such an invasion not only a destruction of the hearing, but also a marked disturbance of the sense of equilibrium—for it is in the ampullæ that the centres which govern this special sense are believed to be located. As a matter of fact, these are precisely the conditions which are established in a goodly percentage of the cases of this epidemic disease; a staggering or an uncertain gait being a prominent symptom for weeks after the patient has in other respects recovered health.

There are other infectious diseases in which the hearing —of one ear only, as a rule—is suddenly or rapidly destroyed, and yet the closest scrutiny fails to furnish any evidence which would warrant us in assuming that the destroying agents have reached the auditory nerve by way of the tympanic cavity. Mumps or epidemic parotitis is one of these diseases, and syphilis is another. As regards both of them, we are forced to draw the conclusion that the specific micro-organisms of the disease are conveyed to the

nerve by the help of the blood-stream, but we are not yet able to state in what particular part of this nerve—from its origin in the medulla oblongata to its distribution among the organs of Corti—they inflict the damage. In the case of mumps, the harm seems to be effected rapidly—in the course of one or two days—and to be irremediable; whereas in syphilis the trouble advances much more slowly, and in not a few of the cases treatment has been found to be effective in restoring the hearing, even after it has seemingly been completely destroyed.

For the sake of orderliness I will here classify, as best I can, the different pathological conditions of the auditory nerve and labyrinth as they have been observed in actual practice. The diagnoses made, although largely hypothetical, possess nevertheless the quality of reasonableness. The different classes which I have adopted are not separated from one another by well-marked boundary lines.

2. Ménière's Disease.

The term "Ménière's disease" is properly applicable to all those cases of apoplectiform deafness (not growing out of such diseases as the mumps, epidemic cerebro-spinal meningitis, etc.) in which the symptoms warrant us in entertaining the belief that a hemorrhage has taken place into the labyrinth; and in which, furthermore, an examination with the speculum and reflected light reveals the fact that no inflammation is going on in the middle ear. Ménière was fortunate enough, in his famous case, to obtain a post-mortem examination a few days after the occurrence of the characteristic symptoms, and he found the semicircular canals filled with clotted blood, which encroached to some extent upon the cavity of the vestibule. It seems proper, therefore, not to apply the term "Ménière's disease" to those cases in which, although the symptoms may be nearly or quite the same, there is no warrant for believ-

ing that a blood-vessel in the labyrinth has actually ruptured. In this category belong the cases in which, under reflex influences, the labyrinthine vessels are for a certain length of time subjected to marked dilatation (vasomotor paresis).

More recent post-mortem examinations have demonstrated the fact that a hemorrhage may occur in any part of the labyrinth, and clinical observation occasionally brings us in contact with cases in which we can scarcely entertain a doubt that the sudden and permanent loss of the hearing in one ear is due to such a labyrinthine effusion of blood. While a certain number of these hemorrhages may owe their origin to an embolism of some arteriole, others may fairly be attributed to the giving way of one of the venous labyrinthine channels under too great a strain.

Diagnosis.—The sudden or rapid development of a marked degree of deafness, together with vertigo and subjective noises; the fact that the patient hears a vibrating tuning fork (when resting upon the centre of the forehead or vertex) better in the unaffected ear; and, finally, the absence of any demonstrable disease in the tympanic cavity sufficient to explain the symptoms complained of—these are the indications which point to the spontaneous rupture of a labyrinthine blood-vessel.

Prognosis.—In the course of a few days or weeks the vertigo usually disappears, but the impairment of the hearing and the tinnitus (in diminished degree) are likely to remain.

Treatment.—I do not know of any measures which may be adopted in the hope of materially influencing the labyrinthine lesions. In some instances local blood-letting has effected a diminution of the distressing symptom of vertigo.

3. Rupture of a Labyrinthine Blood-Vessel Under the Pressure of too Great a Strain.

On one occasion I was consulted by a musician who had entirely lost the hearing in one ear in the course of forty-eight hours. On inquiry I ascertained that his particular musical instrument was the bass tuba, which often requires violent blowing on the part of the performer. I was unable to discover any other cause to which the rapid loss of hearing might be attributed; and owing to the fact that this loss was not accompanied by the symptom of vertigo, I drew the further inference that the hemorrhage had been confined to the cochlea. The deafness proved to be of a permanent character.

4. The Probable Rupture of Some Minute Blood-Vessel in the Labyrinth During Pregnancy.

The sudden or rapid loss of the hearing in one ear during the pregnant condition is not so very uncommon an event; and in some of these cases the loss proves to be only of a temporary nature. From this fact it is permitted to draw the inference that under favorable conditions the effused blood may undergo absorption and thus permit the terminal apparatus of the auditory nerve to resume its functional powers. A hemorrhage into the scala tympani, for example, would not be very likely to cause a permanent loss of the hearing power, for this channel contains no specially delicate structures. A slight hemorrhage into the scala vestibuli might also not do any permanent harm, for here, too, the structures are not specially delicate. Reissner's membrane is the only part that would be likely to suffer from the sudden increase in pressure. On the other hand, a hemorrhage in any part of the cochleal duct would scarcely fail to do permanent damage.

5. Labyrinthine Disease Developing in the Course of Mumps or as a Sequel to the Grippe.

In explanation of the sudden loss of hearing which takes place in these cases of mumps we are obliged to fall back upon the hypothesis of a ruptured labyrinthine blood-vessel. In some of those cases in which an attack of the grippe preceded the loss of the hearing power, there seemed to be grounds for the belief that an embolus had plugged the internal auditory artery just before it subdivides to send one branch to the vestibule and semicircular canals, and another to the structures within the cochlea. The prognosis in this class of cases is unqualifiedly bad.

6. Labyrinthine Disease Resulting from Epidemic Cerebro-Spinal Meningitis.

Among the epidemic infectious diseases, epidemic cerebro-spinal meningitis furnishes the largest number of cases in which the labyrinth becomes the seat of serious pathological changes. These changes are now believed to owe their origin to an invasion of a special variety of micro-organisms from the direction of the cranial cavity. Weber-Liel has shown, by direct experimentation, that a free communication exists between the endolymphatic and perilymphatic spaces of the labyrinth and the extra-labyrinthine intracranial spaces, and it is probably by these routes —viz., by way of the aquæductus vestibuli and the aquæductus cochleæ—that the inflammation spreads from the meninges to the labyrinth.

In the most severe cases of this form of meningitis the invasion may extend beyond the limits of the labyrinth—doubtless by way of the two fenestræ—and set up a serious suppurative inflammation of the middle ear.

Prolonged disturbance of the sense of equilibrium and

complete destruction of the hearing are the almost invariable results of such an invasion of the labyrinth.

7. Labyrinthine Disease of Reflex Origin.

There is a limited class of cases in which both of the labyrinthine functions—that of hearing and that of maintaining the equilibrium—seem to suffer for a short time through reflex vasomotor influences which take their start in the stomach or in some other part of the gastro-intestinal domain. So far as one can judge, in the present imperfect condition of our knowledge, the underlying pathological lesions in the labyrinth consist simply of an undue dilatation (vasomotor paresis) of the blood-vessels, together with an escape of a larger or smaller number of lymphoid cells. These pathological conditions would cause an increase in the intralabyrinthine pressure, and this in turn would produce the tinnitus and vertigo which are the characteristic features of these attacks of gastro-intestinal origin. The same effects, it is possible, may be produced by the very opposite conditions—viz., those of an acute anæmia due to spasmodic contraction of the muscular elements of the arterioles; and yet, on the whole, I am disposed to believe that the other hypothesis is the more likely one of the two to be correct.

8. Labyrinthine or Auditory-Nerve Disease due to Poisoning by Wormseed Oil.

Only a very few cases of this nature have been reported in medical literature. The symptoms of poisoning by the oil of chenopodium include severe frontal headache, a high degree of deafness, distressing subjective noises, and a staggering gait; and from these it is fair to infer that a marked degree of hyperæmia must be present in the labyrinth as well as in other intracranial organs.

9. Syphilitic Labyrinthine Disease.

In a person who has had primary syphilis, and in whom at the time there are no discoverable pathological lesions in the middle ear, there may develop, within a short space of time, marked impairment of the hearing or even total deafness, vertigo, and distressing subjective noises; all of which symptoms may very properly—in the absence of facial paralysis or of symptoms indicative of disease in the medulla oblongata, where the centres for the nerves of hearing are located—be referred to the presence of a syphilitic gumma in some portion of the labyrinth. The same condition of things has been observed in children who were believed to be affected with tardily developed inherited syphilis.

The prognosis is not wholly bad in these cases. Dr. D. B. St. J. Roosa, of New York city, has shown that by the employment of large doses of potassic iodide a very useful degree of hearing power may sometimes be restored.

10. Anomalies of Hearing Believed to be Dependent upon Lesions Involving Only the Cochlea.

It is not known what are the lesions which cause a gradual *contraction of the range of hearing* for musical tones or the condition termed *diplacusis* (double hearing). The latter condition probably seems more rare than it really is, because only those sufferers who happen to be musicians are able to give an intelligible account of their symptoms. There are two forms of double hearing—the one termed *diplacusis monauricularis* (in which two distinct musical tones, forming a harmonious chord, are called forth in one ear in response to a single tone), and the other *diplacusis binauricularis* (in which both ears are required for the production of the phenomenon).

11. Anomalies of Hearing of Extra-Labyrinthine Origin.

Subjective noises which can also be distinguished by the physician upon the application of a suitable auscultation tube to the affected ear, are phenomena of very rare occurrence. For their production it is only necessary that a band of cicatricial tissue should press sufficiently upon some arteriole in the vicinity of one of the ossicles (*e.g.*, the stapes). As to the origin of those noises which offer a distinctively musical character—both to the patient and to the examining physician—it is probable that some other explanation than that which has just been given will be required. It is conceivable that a slender band of connective tissue, free at all points except at the opposite ends, may be set in musical vibration by an arteriole which passes in close proximity to one of its points of attachment.

12. Cerebral Embolism Simulating Labyrinthine Disease.

The existence of cardiac disease, at the aortic valves—in one of my patients who was suddenly seized with a severe pain in the head, vertigo, nausea, and loud noises in both ears, and who at the same time saw all objects doubled, and lost completely the power of hearing what was said to him—warranted the suspicion that an embolism had taken place in or near the medulla oblongata. The return of a considerable fraction of the hearing at the end of six days, and the entire disappearance of double vision after the lapse of a few weeks, gave still further strength to this hypothesis. This patient came under my observation nearly thirty years ago, and since then, so far as I can remember, no similar case has presented itself.

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